THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE

VOL. XLIX.

EDITED BY

BENNETT H. BROUGH
SECRETARY
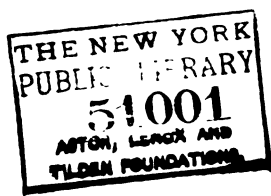
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THE
IRON AND STEEL INSTITUTE.

SECTION I.
MINUTES OF PROCEEDINGS.

ANNUAL GENERAL MEETING.

THE ANNUAL GENERAL MEETING of the IRON AND STEEL INSTI-
TUTE was held at the Institution of Civil Engineers, Great George
Street, London, on Thursday, May 7, 1896—Sir LOWTHIAN BELL,
Bart., Past-President, in the chair.

The CHAIRMAN was sure the members would regret the absence
of the President, but none of them regretted it as much as he
did.   Unfortunately, Sir David Dale's devotion to public and
private affairs, and amongst others, to the Iron and Steel Institute,
had been, more or less, the cause of his temporary seclusion.   He
had gone to take a month's rest, and it was to be hoped that by
that time he would be sufficiently restored to be seen amongst
them as usual.   In the meantime, he (the Chairman) accepted the
responsibility kindly placed upon him, and would do his best to
conduct the business of the meeting in a way which would be
satisfactory to every one.

The SECRETARY read the Minutes of the previous meeting,
which were confirmed and signed.

Mr. G. W. HAWKSLEY and Mr. C. A. WINDER were nominated as
Scrutineers, and on the completion of their scrutiny they reported

that the following gentlemen had been duly elected as members of the Institute :—

Name.	Address.	Proposers.
Ash, Thomas Henry .	Avonmore, Dudley Park Road, Acock's Green, near Birmingham	Josiah Guest, Joseph H. Pearson, Reuben Farley.
Baird, Matthew B. .	Clyde Steel Works, Hamilton, N.B.	Geo. J. Snelus, E. Windsor Richards, Arthur Keen.
Banham, James . . .	9 Edge Hill Road, Nether Edge, Sheffield	Sydney J. Robinson, George Senior, Wm. Edgar Allen.
Bayliss, Thomas Abraham	Thirlmere, Wheeley's Road, Edgbaston, Birmingham	R. A. Hadfield, T. E. Vickers, Sydney J. Robinson.
Bayliss, Thomas Richard, Assoc. M. Inst. C.E.	Belmont, Northfield, near Birmingham.	R. A. Hadfield, T. E. Vickers, Sydney J. Robinson.
Broadway, Benjamin James	267 Hagley Road, Edgbaston, Birmingham	Charles Akrill, W. J. Randon, Samuel Downing.
Brown, Arthur George	38 Victoria Buildings, Manchester	R. A. Hadfield, A. G. M. Jack, E. Windsor Richards.
Cardell, William Parminter	Crawford Street, Wolverhampton	Tom B. Adams, Wm. Hutchinson, Percy J. Adams.
Cooper, Ebenezer Elias	Churchill House, Brierley Hill, Stafford.	Sir B. Hingley, W. J. Randon, Samuel Downing.
Cooper, Myles, M.I. Mech. E. . .	36 Victoria Street, Manchester	W. H. Panton, C. Lowthian Bell, Jeremiah Head.
Cross, John Russell .	Midlot, Mossend, N.B.	James Neilson, Andrew Lamberton, George Russell.
Darby, James . . .	Pedmore, near Stourbridge	James Bennie, George Macpherson, Geo. King Harrison.
Davage, Thomas . .	152 Saville Street East, Sheffield	Lewis J. Firth, Joseph W. Hulse, Harry Marsden.
Ehrensberger, Emil .	Krupp's Steel Works, Essen, Germany	A. Thielen, R. A. Hadfield, A. G. M. Jack.
Ely, Harold	Lombard Street, West Bromwich	Frederick Scarf, Henry Silvester, Richard Mentz Tolley.
Eveson, George James	26 Corporation Street, Birmingham	Joseph H. Bullock, A. E. Horton, E. Horton.
Gilbertson, Francis William, B.A.	Glanrhyd, Swansea Vale	Edw. P. Martin, Alfred Bowen, J. H. R. Ritson.
Hirst, Thomas Benjamin	Gwernllwyn, Uchaf, Dowlais, Glam.	Edw. P. Martin, Daniel J. Hirst, Alfred Bowen.
Hopper, John Ingledew	Wire Rope Works, Thornaby-on-Tees	Sir David Dale, William Whitwell, David Evans.
Hotta, Rentaro . . .	13 Hara Machi, Koishi - Kawa, Tokyo, Japan	Charles Wood, W. Gowland, J. E. Stead.
Humfrey, Charles . .	The Poplars, Winnington Park, Northwich, Cheshire	Sir David Dale, Geo. J. Snelus, John H. Darby.

Name.	Address.	Proposers.
Jenks, Harry Maze .	Heath Town, Wolverhampton	Robert Heath, George Harding, W. R. Lysaght.
Jenks, Joseph, jun. .	Heath Town, Wolverhampton	A. W. Hutton, J. Maybery, Robert Heath.
Kendal, Ramsey, M.I. Mech. E.	North Road, Darlington	Sir David Dale, Sir Lowthian Bell, Sir James Kitson.
Lindberg, Lars Uno .	Kohlswa, Sweden	A.G. Ljungberg, E. J. Ljungberg, J. J. Pickford.
McWilliam, Andrew, Assoc. R.S.M.	Ryder's Chambers, Spring Head, Wednesbury	James Roberts, Thomas Turner, Walter G. McMillan.
Mantle, Harry George, F.G.S.	Old Level Ironworks, Brierley Hill	Richard Mentz Tolley, Frederick Scarf, George Hatton.
Martin, Edwin H. . .	Coatesville, Pa., U.S.A.	Horace W. Lash, Alfred E. Hunt, George H. Clapp.
Miller, Alexander R. .	Globe Ironworks, Motherwell, N.B.	George Beard, George Garrett, James Kerr.
Mills, Frederick . .	Glasgow Iron and Steel Co., Limited, Wishaw, N.B.	James Riley, Douglas Upton, Frank W. Dick.
Mogren, Adolf . . .	164 Edmund Street, Birmingham	Frederic Smith, A. G. Ljungberg, D. Stephens.
Monks, Frederick William	Warrington	F. Monks, W. H. Hewlett, John H. Darby.
Morel, Thomas	Cardiff	Edw. P. Martin, J. Pearce Roe, W. Thomas.
Page, Charles Harry .	The Eagle House, Penn Field, Wolverhampton	George North Adams, John Page, Alexander McBean.
Pearson, Richard Thomas	Old Hill, Stafford.	Alex. E. Tucker, John I. Parkes, Walter Somers.
Pease, Reginald . .	Pierremont, Darlington	Sir David Dale, Sir Joseph W. Pease, Thomas Putnam.
Piercy, Henry James Taylor	Broad Street Engine Works, Birmingham	Thomas Cumberland, John Speight Cumberland, H. Le Neve Foster.
Pool, Anthony . . .	Staffordshire Steel and Ingot Iron Co., Limited, Bilston	Wm. Hutchinson, W. Moore, Alfred Colley.
Proctor, James . . .	Lilleshall Company, Oakengates, Salop	Alex. E. Tucker, Walter Somers, H. Le Neve Foster.
Rathbone, Andrew .	Bewsey Cottage, Warrington	W. H. Hewlett, Thomas M. Percy, E. H. Saniter.
Richards, Arthur Windsor	Lothian Road, Middlesbrough	David Evans, Edw. P. Martin, Arthur Keen.
Rigo, Eugéne . . .	Hautmont, France	P. Trasenster, Armand Sepulchre, A. Greiner.
Roberts, Caleb William	Hill View, Brierley Hill, Stafford.	Sir B. Hingley, W. J. Randon, Samuel Downing.
Shipman, George A. .	Attercliffe Steel Works, Sheffield	John W. Shipman, Ambrose Firth, R. A. Hadfield.
Schönwälder, Otto .	Dillingen, a/d Saar, Rhenish Prussia	Joseph Bedford, Thos. Blair, L. Napier Ledingham.
Scott, Herbert . . .	Miguel Burnier, Minas, Brazil	Edward Riley, T. Twynam, Joseph Torbock.

NAME.	ADDRESS.	PROPOSERS.
Simons, William	6 Morlais Street, Dowlais, Glam.	Edw. P. Martin, William Evans (Dowlais), William Evans (Cyfarthfa).
Somers, Seth Smith .	Haywood Forge, Halesowen	Sir B. Hingley, Alex. E. Tucker, James Roberts.
Stouls, Armand . . .	Quai Orban, 61 Liége, Belgium	P. Trasenster, A. Greiner, Alfred Maroquin.
Suppes, Max M. . .	The Johnson Co., Lorain, Ohio, U.S.A.	Edw. P. Martin, E. Windsor Richards, David Evans.
Thomas, Harold Massey	Whitchurch, near Cardiff, Glam.	Edw. P. Martin, Sir W. Thomas Lewis, R. Beaumont Thomas.
Thornewill, Robert .	Burton-on-Trent	Robert Heath, Chas. R. Western, George Harding.
Wadham, Arthur . .	60 Jermyn Street, London, S.W.	David Evans, Arthur Keen, Edw. P. Martin.
Warden, Francis Hollins	Lionel Street, Birmingham	J. Bayley Lees, George Harding, John D. Wragg.
Watts, William . .	165 Pitsmoor Road, Sheffield	R. A. Hadfield, T. G. Richardson, W. T. Flather.
Wedemeyer, Christian Francis, M.A. . .	North Lincoln Iron Works, Scunthorpe, near Doncaster	Ernest Bellhouse, Joseph Adamson, Walter Crooke, jun.
Wyman, Ronald . .	82 Brunswick Street, Broomhall, Sheffield.	W. H. Hewlett, Edward Steer, Edw. P. Martin.

The SECRETARY then read the following Report of the Council upon the proceedings of the Institute during the year 1895 :—

REPORT OF COUNCIL.

AT this twenty-seventh Annual General Meeting of the Iron and Steel Institute, the Council have the pleasure of presenting to the members their Report on the Proceedings of the Institute, and are glad to note that during the year 1895 the work of the Institute has been carried on with the most encouraging results. The satisfactory progress made by the Institute is reflected in the accompanying statement of receipts and expenditure.

THE ROLL OF THE INSTITUTE.

The number of members on the roll of the Institute on December 31, 1895, was 1555. During the year there were added to the register 93 names, a number slightly above the average of the previous five years, as is shown by the following statistics:—

Year.								New Members.
1890	.	.	.	.	.	.	.	170
1891	.	.	.	.	.	.	.	76
1892	.	.	.	.	.	.	.	55
1893	.	.	.	.	.	.	.	45
1894	.	.	.	.	.	.	.	114
Average	.	.	.	.	.	.	.	92

With the aim of keeping the status of the Institute as high as possible, the Council have, as usual, carefully scrutinised the qualifications of candidates for election, and have taken care that those recommended for ballot are either persons practically engaged in works where iron or steel is produced or worked, or persons of metallurgical attainments, or specially connected with the application of iron or steel.

The Council have to congratulate several members of the Institute on high distinctions obtained by them. Baronetcies have been conferred by Her Majesty upon the President, Sir David Dale, and upon Sir William Thomas Lewis, member of Council, and a Knighthood upon Sir Acquin Martin, member of the Institute. Dr. William Anderson has been appointed to be a Companion of the Order of the Bath. The Albert Gold Medal of the Society of Arts was presented by the Prince

of Wales to Sir Lowthian Bell, Bart., Past-President, and the Senate of Durham University has conferred the honorary degree of Doctor of Civil Law on the President, Sir David Dale. A prize of two thousand francs has been awarded by the *Société d'Encouragement pour l'Industrie Nationale* to Mr. F. Osmond for his researches on the microscopic structure of steel; a Gold Medal has been awarded by the same Society to Mr. R. A. Hadfield, member of Council, for his metallurgical researches; and the Elliot Cresson Gold Medal of the Franklin Institute of Philadelphia, and the Gold Medal of the *Verein zur Beförderung des Gewerbfleisses* have been awarded to Mr. H. M. Howe, Bessemer Gold Medallist, for his researches on the properties of iron.

During the year under review the Institute has suffered great losses by the death of several of its distinguished members, the following twenty-six deceases of members having been reported:—

Bantock, Thomas (Wolverhampton) . .	July 21, 1895.
Buckley, James (Llanelly)	September 2, 1895.
Chadwick, David (London) . . .	September 19, 1895.
Deby, Julien Marc (Sheffield) . . .	April 14, 1895.
Dickinson, Richard Elihu (Bradford) .	May 12, 1895.
Fellows, Samuel James (Wolverhampton) .	March 1895.
Fincken, Christopher Wm. (Barnsley)	April 1895.
Gruson, Hermann (Magdeburg-Buckau)	January 1895.
Hodgson, John (Darlington) . .	January 5, 1895.
Jambille, Simon Louis François (Maubeuge) .	January 14, 1895.
Jenkins, William (Consett) . . .	May 14, 1895.
Mitchell, Charles (Newcastle-upon-Tyne)	August 22, 1895.
Mitchell, Joseph (Warth-upon-Dearne)	April 18, 1895.
Nicholas, Evan (Merthyr Tydvil) .	May 16, 1895.
Noble, James (Middlesbrough) . .	October 22, 1893.
Pochin, Henry Davis (Denbighshire) .	October 28, 1895.
Poensgen, Rudolf (Düsseldorf) . .	April 1895.
Schulz, Gustav (Wiesbaden) . .	April 1895.
Seebohm, Henry (Sheffield) . .	November 26, 1895.
Taylor, Thomas Albert Oakes (Leeds) .	August 22, 1895.
Thomas, John Glyn (Llangenneck) .	1891.
Thomson, George (Cheltenham) . .	November 30, 1894.
Tolmie, Andrew Denny (Glasgow) .	November 6, 1895.
Williams, John William (Kerry)	March 7, 1895.
Williams, David (Mold)	June 18, 1895.
Wood, John (Troon)	September 18, 1895.

Of these, Mr. Jenkins was one of the original members of the Institute, and always took a warm interest in its welfare. He was elected a member of Council in 1880, and a Vice-President in 1888. In 1887, with characteristic generosity, he presented to the Institute a portrait in oils of the late Edward Williams, Past-President.

On the foreign list, members have to lament the loss of Messrs. Gruson, Poensgen, and Schulz, the distinguished German ironmasters, and of Mr. Jambille, the Vice-President of the *Comité des Forges* of France. Particulars of the professional careers of the deceased members will be found in the obituary notices in the Journal of the Institute.

In consequence of the non-payment of subscriptions, the names of twelve gentlemen have been removed from the list of members, and there have been sixteen resignations of membership.

FINANCE.

The income of the Institute in 1895 was of the ordinary character. On comparing the figures for 1895 with the average of those for the previous five years, it will be noticed that the receipts from annual subscriptions are materially above the average. The expenditure was of a normal character and below the average outlay for the past five years.

The statement of accounts for the year ending December 31, 1895, is now submitted to the members by the Honorary Treasurer. It will be observed that the income during 1895 amounted to £4159, 7s. 5d., and the expenditure to £3088, 6s. 7d., the surplus being £1071, 0s. 10d.

The corresponding figures for the five previous years are appended :—

			Receipts.			Expenditure.		
			£	s.	d.	£	s.	d.
1890	.	.	3805	16	3	3841	12	1
1891	.	.	3742	6	10	2767	6	11
1892	.	.	3627	3	5	3942	7	3
1893	.	.	3589	11	0	3899	15	2
1894	.	.	3749	3	3	3074	1	9
1895	.	.	4159	7	5	3088	6	7

MEETINGS.

Two general meetings were held as usual during the past year. By the courtesy of the Council of the Society of Arts, the Spring Meeting was held on May 9th and 10th at the house of that Society.

In addition to the President's admirable and instructive address, the

papers contributed to the Institute's proceedings during the year were as
follows :—

1. On Metal Mixers, as used at the Works of the North-Eastern
   Steel Co., Limited. By A. COOPER.
2. On the Effect of Arsenic on Steel. By J. E. STEAD.
3. On the Mines of Elba. By H. SCOTT.
4. On the Manufacture of Steel Projectiles in Russia. By S. KERN.
5. On Ternary Alloys of Iron. By J. S. DE BENNEVILLE.
6. On the Iron Industry of South Staffordshire. By D. JONES.
7. On the Mineral Resources of South Staffordshire. By H. W.
   HUGHES.
8. On the Direct Puddling of Iron. By E. BONEHILL.
9. On the Ironworks of the South of Russia. By G. KAMENSKY.
10. On the Thermo-Chemistry of the Bessemer Process. By W. N.
    HARTLEY.
11. On the Production of Iron by a New Process. By R. A. HAD-
    FIELD.
12. On a New Method for the Analysis of Chrome Ore. By E. H.
    SANITER.
13. On Nickel Steel, and its Advantages over Ordinary Steel. By
    H. A. WIGGIN.
14. On Small Cast Steel Ingots. By R. SMITH CASSON.
15. On Cooling Curves and Tests for Cast Iron. By W. J. KEEP.
16. On Tests of the Physical Properties of Cast Iron. By T. D.
    WEST.
17. On the Hardening of Steel. By H. M. HOWE.
18. On the International Congress for Unification of Methods of
    Testing. By G. LUNGE.
19. On an Exhibition Illustrative of the Industries of Birmingham.
    By W. G. McMILLAN.

The international character of the proceedings of the Iron and Steel
Institute is well shown in this list, in which it will be noticed that of
the nineteen papers four have been contributed by American metallur-
gists, two by Russians, one by a Belgian, and one by a Swiss, whilst the
discussion and correspondence on the papers published in the Journal
embrace valuable contributions from American, Belgian, French, German,
Spanish, and Swedish members.

The Autumn Meeting, held at Birmingham, a city not previously visited

by the Institute, was attended by 550 members, that being the largest attendance yet recorded at any meeting of the Institute. The members were received with magnificent hospitality by an influential Local Committee, and an elaborate programme of visits and excursions of exceptional interest was arranged. To Sir Benjamin Hingley, Bart., as chairman of the Local Reception Committee, to Mr. Arthur Keen, Hon. Treasurer, and to Mr. Leigh H. Elkington, Hon. Secretary, the warmest thanks for the arrangements are due. The brilliant success of the Birmingham meeting, the cordiality of the reception, and the profuse hospitality cannot fail to be long remembered by the members.

The annual dinner of the members of the Institute was held on May 9, 1895, at the Freemasons' Tavern. The chair was taken by the President, and there was a very large attendance of members and their friends. The list of speakers included the names of the United States Ambassador, the Duke of Devonshire, Lord Kelvin, President of the Royal Society, Sir Benjamin Hingley, Bart., Sir James Kitson, Bart., M.P., Sir Courtenay Boyle, K.C.B., Sir Alfred Hickman, M.P., General F. T. Lloyd, C.B., Professor Roberts Austen, C.B., and Mr. Windsor Richards.

The Council are indebted to Mr. William Gill for taking the preliminary steps whereby they are enabled to announce that the Autumn Meeting will be held in Bilbao on September 1st and following days. Assurances of a hospitable reception have been received, and opportunities will be given for visiting most of the ironworks and mines in that important mineral district, from which so large a proportion of the iron ore used in Great Britain, France, and other countries is obtained.

PUBLICATIONS.

Of the Journal of the Institute two volumes have been published during the past year; the two volumes together containing 1229 pages of letterpress and 53 plates. In addition to the papers read before the Institute, and the discussion and correspondence relating to them, the volumes contain abstracts of 1201 papers relating to iron and steel and kindred subjects published in other home and foreign technical journals and transactions. In view of the frequent applications made to the Institute for detailed particulars of the methods and appliances referred to in these abstracts, there can be no doubt that they constitute a useful feature of the Journal. Endeavours are invariably made to secure copies of the originals for the Library, in order to render them available for the perusal of members desirous of obtaining fuller details.

LIBRARY.

Numerous presentations to the Library have been made, a list of which is given in the Journal of the Institute. For these the Council record their thanks to the several donors. Members are invited to present original pamphlets relating to iron and steel, and other works valuable for reference, which are always welcome, for permanent preservation.

The Council is glad to note that the number of members using the Library continues to increase. Additional bookshelf accommodation has been provided to meet the growth of the Library ; a new card catalogue is in progress, and considerable progress has been made during the past year towards filling up the gaps which unfortunately exist in many sets of technical serials.

The additions to the collection of portraits of Bessemer Gold Medallists include a portrait of Lord Armstrong, presented by his Lordship, and portraits of Mr. James Riley, Vice-President, Mr. Arthur Cooper, member of Council, Mr. W. D. Allen, and Mr. H. M. Howe, presented by those gentlemen.

THE BESSEMER MEDAL.

The Bessemer Gold Medal for 1896 has been awarded to Dr. Hermann Wedding, Professor at the Berlin School of Mines, in recognition of the services he has rendered to the iron and steel industries by his valuable contributions to metallurgical literature.

STEEL RAILS COMMITTEE.

The Board of Trade having expressed the wish that the Iron and Steel Institute should select two members for a proposed Committee on Steel Rails, the Council selected Mr. E. Windsor Richards, Past-President, and Mr. E. P. Martin, Vice-President, as representatives of the Institute on that Committee. The conclusions in the report of Major Marindin with regard to an accident which occurred on November 10, 1895, at St. Neot's Station, on the Great Northern Railway, appeared to the Board of Trade to furnish ground for supposing that molecular action of some not precisely ascertained nature might be going on in steel rails of a certain age, and subjected to a certain strain-action, which under circumstances might cause risk of serious accident. The Board of Trade had consequently determined to appoint a Committee to inquire into the extent of loss of strength in steel rails, produced by

their prolonged use on railways under varying conditions, and what steps could be taken to prevent the risk of accidents arising through such loss of strength.

RETIRING MEMBERS OF COUNCIL.

There have been several changes on the Council during the past year. Mr. Andrew Carnegie was elected Vice-President to fill the vacancy caused by Mr. William Whitwell's having accepted the position of Treasurer, and Mr. F. W. Webb was elected to fill the vacancy thus caused. The lamented decease of Mr. William Jenkins created a vacancy among the Vice-Presidents, which was filled by the election of Mr. Arthur Keen, whose place on the Council has been filled by Mr. J. E. Stead, F.I.C. The members of Council who retire in rotation, in accordance with Rule 10, are :—

Vice-Presidents.

Mr. W. H. Bleckly.   Mr. E. P. Martin.
Sir James Ramsden.

Members of Council.

Mr. V. C. W. Cavendish, M.P.   Mr. David Evans.
Mr. Arthur Cooper.   Mr. William Evans.
Mr. A. T. Walker.

As no other candidates have been nominated, these gentlemen, who, with the exception of Sir James Ramsden, are eligible, are presented by the Council for re-election. In the place of Sir James Ramsden, who has been compelled by a serious failure of health to resign his membership of the Institute, the Council have unanimously elected Mr. Alexander Thielen, as Vice-President, and have pleasure in presenting Sir Alfred Hickman, M.P., for election as member of Council to fill the vacancy thus caused.

The Treasurer (Mr. WILLIAM WHITWELL) read the Annual Statement of Account for the year 1895 (p. 12).

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1895.

INCOME.

To Entrance Fees	£191 2 0
,, Subscriptions	3150 0 0
,, Subscriptions in advance . .	25 4 0
,, Life-Composition . . .	31 10 0
,, Journal sales	128 19 0
,, Messrs. Ballantyne, Hanson & Co., in respect of Journals destroyed by fire in 1891 }	333 12 6
,, Interest on Investments . .	283 10 8
,, Bessemer Medal Fund Interest .	15 9 8
	£4159 7 5

EXPENDITURE.

By Balance due to Treasurer, December 31, 1894		£918 7 11
,, Salaries	£885 2 0	
,, Office Rent, Cleaning, &c. .	334 18 4	
,, Library, Books and Binding .	33 9 0	
,, Office Furniture and Repairs	23 14 5	
,, Translating . . .	143 18 0	
,, Annual Meeting Expenses (London)	49 10 6	
,, Autumn Meeting Expenses (Birmingham)	185 12 11	
,, Journal Publishing Expenses	920 17 1	
Postages . .	86 9 11	
,, Postages and Receipts	99 8 11	
,, Printing and Stationery	266 8 10	
,, Insurance . .	1 15 0	
,, Bessemer Medal	14 16 0	
,, Corporation Duty	27 0 8	
,, Sundry Payments		
		3088 6 7
,, Balance due from Treasurer		157 12 11
		£4159 7 5

(Signed)   WILLIAM WHITWELL, Hon. Treasurer.
                BENNETT H. BROUGH, Secretary.

May 7, 1896.

INVESTED FUNDS OF THE INSTITUTE.

£1500 North-Eastern Darlington 5½ per cent. Stock, purchased at a cost of . .	£2298 7 0
£1681 North-Eastern 1876 4 per cent. Preference Stock, purchased at a cost of .	1908 19 7
£630 North-Eastern Darlington 5 per cent. Stock, purchased at a cost of .	1008 14 0
£1546* Scinde, Punjaub, and Delhi 5 per cent. Stock, purchased at a cost of .	1999 0 7
£750 Great Indian Peninsula Railway 5 per cent. Stock, purchased at a cost of	1267 6 0
	£8572 7 2

* This has since been compulsorily converted into an Annuity up till 1968, with a Sinking Fund to replace the amount of Stock, £1546.

The TREASURER, speaking generally, said the accounts were in a satisfactory condition. The number of members had been improving. The income had considerably increased, and the Council was gratified to be able to place before the members so clear a statement of accounts left by their late excellent treasurer, Sir David Dale, to whom their indebtedness could never be sufficiently acknowledged.

The income of the Institute for the year ending December 31st, 1895, showed an increase of £410, 4s. 2d. as compared with the previous year. Of that sum £333, 12s. 6d. was in respect of exceptional income, being the amount paid by Messrs. Ballantyne, Hanson & Co. for a number of unbound Journals which they had been good enough to store at their works, and which were unfortunately destroyed by fire in 1891. The nett increase in ordinary income was, therefore, £76, 11s. 8d. The receipts from entrance fees showed a decrease of £48, 6s. 0d., whilst there was also a falling off in Journal sales of £37, 1s. The amount received for subscriptions was £161, 14s. in excess of the previous year. The surplus of ordinary income over expenditure was £737, 8s. 4d.

The expenditure during the year had been of an ordinary character, and showed a nett increase of £14, 4s. 10d. As would be seen from the Statement of Account, a sum of £33, 9s. had been spent upon books, &c., for the library, and a sum of £23, 14s. 5d. on office furniture, including the cost of a new fireproof safe. The item "Autumn Meeting Expenses" included a sum of £23, 19s. 2s. for the members' badges for the Birmingham meeting.

The Treasurer added that he had submitted the accounts to Messrs. William B. Keen & Co., a firm of chartered accountants who had had great experience with the accounts of the Royal Society, the British Association, the Geological Society, and other learned societies, and the report of the head of the firm was as follows :—

" I have examined the accounts of the Iron and Steel Institute in respect of the year ended December 31st, 1895, and beg to report to you thereon.

" The expenditure included in the Statement of Accounts amounts to

£3088, 6s. 7d., the whole of which has been vouched for to my satis-
faction. This expenditure was not all made during the year 1895, but
includes payments relating to the year which have been made during
1896, and excludes payments relating to 1894 which were made in the
early part of 1895, this having been the system upon which the accounts
have hitherto been prepared. Similarly the receipts, amounting to
£4159, 7s. 5d., include certain receipts in the early part of 1896, and
exclude similar receipts in the early part of 1895."

The CHAIRMAN moved that the Report be received and adopted.

Mr. ARTHUR KEEN, Vice-President, seconded the motion,
which was unanimously adopted.

Mr. JEREMIAH HEAD moved—"That the most cordial thanks
of the members of the Iron and Steel Institute be and are hereby
tendered to the President, Council, and Hon. Treasurer for their
services during the past year." Their worthy Secretary had an
inveterate habit of asking him to propose that resolution. He
supposed it was because, being one of the original members of the
Institute, of whom unfortunately very few now survived, it was
thought that he had sufficient experience to be able to compare
the work of the Council, the President, and the Treasurer of the
present year with past years, and also perhaps with other societies
with which he was connected. Looking at the matter in that
light, he was of opinion, and he thought that the members gener-
ally would agree with him, that the work of the Council during
the past year had been very arduous and very successful. No
body of men could have done more than they had done in the
interests of the Institute, and the least the members could do was
to tender them their very cordial thanks. He was glad to know
that the funds of the Institute were in a very satisfactory condi-
tion. He did not quite gather from the Treasurer's remarks
what the total value of the property was at the present time. It
appeared to be so much that the Treasurer shrank from saying
what it was, for fear of elating them too highly. It was quite
evident that his part of the work had not been done without very
great assiduity and very great attention. The publications of the
Institute were becoming of greater and greater value every year,
and he had no doubt that the members felt that their libraries

would be quite incomplete without them. He was sure they all echoed the words of Sir Lowthian Bell with regard to the illness of their worthy President. Unfortunately, it seemed to be a way now-a-days that some men had far too much to do and others far too little; and it would be a very good thing if they could put some of the work of others who had too much to do on those who had too little. Sir David Dale was a man who, whatever he did, did it well and conscientiously, never sparing himself. He was sure the members would all agree that it was very unfortunate that illness should prevent the President from attending on the present occasion.

Mr. F. W. HARBORD had great pleasure in seconding the proposition. The members would, he was sure, agree with him that the gentlemen who had given so much of their valuable time to the interests of the Institute, coming from all parts of the United Kingdom to take part in its efficient working, deserved their hearty thanks for the manner in which they had conducted the business during the past year.

The motion was unanimously adopted.

The CHAIRMAN said it was his duty to acknowledge the vote of thanks just passed to the Council. Mr. Head had spoken of a habit being inveterate. No doubt, when a habit was a bad one, it was much to be condemned, but when the habit was not a bad one, as he himself had proved, it was much to be commended. The members would, he thought, agree with him, as the Council certainly would, that Mr. Head had done them ample justice in the remarks he had made. In the Report he believed it would be found that every one who had had anything to do in connection with the meetings and the business of the Institute had been referred to in suitable terms. As one who had had much to do with his election, and had had an opportunity of judging of the admirable way in which the Secretary performed his duties, he thought he was only doing strict justice in mentioning his impressions of the manner in which Mr. Brough had conducted the work of his office.

The next business was the presentation of the Bessemer

Medal. Great changes had taken place in the twenty-seven years mentioned by the Secretary in the constitution of the Institute. Unfortunately they had to deplore the deaths of many of their friends. Other changes had also brought a great deal of fresh blood into the ranks of the members, and it, perhaps, might be fitting enough that he should enable the younger members to have some idea of the origin and character of the Bessemer Medal. That medal, thanks to the munificence and liberality of his distinguished friend, Sir Henry Bessemer, was placed at the disposal of the Council for the following purposes. To award it to any one who might suggest any remarkable invention of mechanical or chemical processes connected with the manufacture of iron and steel; for any paper read, or contributions to the Journal, or original investigation bearing on the manufacture of iron and steel; and to any one not coming strictly under the foregoing definition who by their conduct might have benefited the iron and steel trade. Their body, as was well known, might be considered one strictly of British origin, but it had opened its doors to gentlemen from all parts of the world. One was very far distant, Afghanistan. He did not know whether he was a native of that country, but they certainly had on their list a native of Japan. They had, he believed, as their foreign friends would acknowledge, done their best to be impartial with regard to the Bessemer Medal. It would be sufficient to remind the members that out of the twenty-four adjudications that had been made, ten had been awarded to foreigners, including the late Sir William Siemens and Mr. Gjers, who, though naturalised Englishmen, were regarded as natives of a foreign country. Ten out of twenty-four was not a bad proportion when it was remembered that out of the 1600 members only one-fifth belonged to other countries.

He desired to emphasise the value of the Bessemer Medal. Its great value, in his eyes, arose from the fact that it was the gift of their distinguished friend, Sir Henry Bessemer, and nothing had happened since that gift was made which had tended to dim in the slightest degree the lustre of the precious metal of which it was composed. To speak in very mild terms of the invention widely and honourably known as the Bessemer process, it had revolutionised the iron manufacture of

the country, and, indeed, of the world, and it still remained as fixed an element in the history of the iron trade as it could possibly be.

He begged leave to mention an incident which occurred to his mind in connection with the events of the present day. Many of the members who had the opportunity of taking part in the very munificent and magnificent reception at the hands of their friends in America, would remember that there was one single drawback in connection with it. The first question put to them on the occasion was, Where is Sir Henry Bessemer? Every one had hoped to have the opportunity of seeing the distinguished inventor of a very large industry now conducted in the United States. Sir James Kitson being aware that Sir Henry Bessemer was prevented from attending owing to circumstances connected with the state of his health, took the opportunity of submitting an autograph letter from the inventor, giving an account of his early experiments, and of that a photographic reproduction was prepared and presented to all the members of the American Institute of Mining Engineers at the meeting at Pittsburg. He mentioned that to show that it was not only in England, but throughout the world, that the value and importance of Sir Henry Bessemer's invention had been abundantly recognised.

On the present occasion they had selected as a proper recipient of the medal a gentleman who, in his own country, was a distinguished professor of metallurgy; a friend of his own of many years' standing, Dr. Hermann Wedding. He (the Chairman) was greatly in favour of awarding the medal, wherever it could be suitably done, to those gentlemen who, with singleness of purpose, and in utter oblivion of their own personal advancement, as far as pecuniary considerations were concerned, devoted their time to help practical workers in iron and steel in every way by the dissemination of scientific truths; and there was no one who had laboured in that capacity more assiduously and with greater success than Dr. Wedding. He had therefore great pleasure on behalf of the Institute, and on behalf of Sir Henry Bessemer himself, in presenting the medal for the present year to Dr. Wedding, for his distinguished services in connection with the metallurgy of iron and steel.

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Dr. WEDDING, in receiving the medal, said he was duly aware of the honour bestowed upon him by the presentation. It had been presented not only to himself, but, through him, to German technical scientists. He was sure that the distinction would be appreciated by all his countrymen and colleagues, more especially as he believed he was the first German subject who had received the medal. If he had done anything in his metallurgical work worthy of mention it had been the outcome of an endeavour to be of use to his Fatherland. But, happily, science was in the true sense of the word international, and knew no bounds or limits. He valued the honour the more because the medal was a British one, as he was indebted for a great part of his technical knowledge to the English. As far back as in the years 1860 and 1862 he had the opportunity of seeing all the large iron works in England and studying them; and an excursion through England and Scotland with the eminent head of the Prussian Department of Mines, Mr. Krug von Nidda, in 1863, gave him other opportunities of seeing the progress that had been made in the British iron industry. In 1860, too, through the extreme kindness of their revered friend, Sir Henry Bessemer, he was afforded an opportunity of studying his newly-invented process earlier than most of his countrymen. He was able to appreciate the value of that marvellous invention, which had revolutionised the whole iron industry in a few years, not only in England, but in all other countries. At his instigation the Bessemer works at Hoerde in Westphalia were built, and he designed the Bessemer works at Königshütte in Silesia. He had invariably upheld his opinion, against many prejudices, in favour of Bessemer steel, which bore in Germany the name of *Flusseisen*, which he originated. He felt therefore very great pleasure in receiving the medal bearing the name of the great inventor. His intimate connection with his dear friend, the late Dr. John Percy, President of the Iron and Steel Institute, whose valuable book had been the foundation of his (Dr. Wedding's) extensive works on iron metallurgy, and his connection with the members of the Iron and Steel Institute in far-off countries, in Hungary, for example, and in the United States, had always led to very friendly feelings between himself and British ironmasters. He hoped that the honour bestowed upon him that day would create still stronger ties between

English practice and German science for the benefit of both countries.

Sir HENRY BESSEMER, Past-President, rose on that occasion with very strong feelings of gratitude, because when a man's labours were acknowledged in the handsome way in which his had been, he could but feel that his labour had met with its reward.   No doubt, the invention which he had the honour of originating had been a source of great change.   It must probably have been a considerable loss to those who had invested large sums in the old form of manufacture, and that was a source of regret to himself; but the fact that those old modes had been replaced by one which produced a material so much more valuable for structural purposes than that produced by the old methods afforded, he´ thought, ample compensation under the new circumstances.   He had not intended to address the meeting, but the few observations that had fallen from Sir Lowthian Bell and from Dr. Wedding seemed to call for an acknowledgment on his part, and he begged leave to assure the members that no one could feel more gratified than he did at the appreciation of men whose opinions like theirs had so much weight.

The following paper was then read :—

THE FORD AND MONCUR HOT-BLAST STOVE.

BY BENJAMIN JAMES HALL.

THE writer's apology for presenting this paper must be found in the fact that, whilst descriptions and illustrations of the Cowper, Whitwell, and Crooke types of hot-blast firebrick stove are to be met with in the pages of the Journal of the Iron and Steel Institute, no such detailed information is available therefrom regarding the Ford and Moncur patent, a type, the results of which have been so uniformly excellent during the twelve years which have passed since the first stoves were put to work, that it is daily growing in favour, and some of the most successful companies in this country are working their furnaces exclusively with stoves of this construction.

In order to make the arrangement as clear as possible, diagrams, taken from the working drawings of one of the latest stoves, 72 feet high by 26 feet diameter, have been specially prepared to accompany this paper. These are shown in Plates I., II., and III. A brief description of the principal points is all that is necessary to render the drawings perfectly intelligible.

The brickwork is enclosed in the usual air-tight cylindrical casing of wrought iron or mild steel plates. The crown-plate of the dome is attached with bolts and nuts, and forms a manhole lid, the only provision now made for obtaining access to the internal structure from the upper part of the stove. A minimum space of half an inch is allowed for expansion between the casing and brick lining. The combustion chamber is rectangular, and extends transversely the full width of the stove. In the upper part is an auxiliary regenerator, formed of 9-inch and $4\frac{1}{2}$-inch walls carried on brick arches and special tiles, leaving parallel passages about 18 inches by 12 inches, as shown in Figs. 1, 2, and 3. The semicircular spaces on both sides of the combustion chamber are filled with regenerative brickwork, consisting of parallel walls $2\frac{1}{4}$ inches thick, built dry, and held in position by stays of elliptical

section with square ends, spaced zigzag as shown in Figs. 1 and
6.   Each semicircular space is divided into two equal portions by
a cross wall 14 inches thick, extending from the base to the top
of the stove, and uniting with the central division wall of the
auxiliary regenerator; one half of this latter is thus common to two
main regenerative compartments.   Below the grids carrying the
division walls in each compartment is a vacant space communicat-
ing with the central flue leading to the chimney valve, through an
opening formed in the division wall, in which is fixed an internal
valve operated from the outside of the stove by screw and hand-
wheel.   These four valves constitute a feature in the arrange-
ment, for by them the quantity of air passing through any of the
compartments can be controlled at pleasure, and the blast may
be regulated to maintain an approximately constant temperature
throughout a two hours' blow, if at the commencement of blow-
ing two or more compartments be shut off and held in reserve, to
be gradually brought into action as the temperature begins to
fall.   With all the valves open, the fall in temperature in a two
hours' blow seldom exceeds 60° F., and in consequence this
method of working is never adopted.   In Cumberland the blast-
furnaces are usually worked at 1350° to 1400° F., and the stoves
at 1500° F.   The temperature is regulated to suit the require-
ments of the furnace by adjustment of a cold-blast valve placed
close to the circular main.

At the end of the central flue is a balanced mushroom valve
similar to that generally in use, by which connection is made
with the chimney flue.   The instantaneous valve immediately in
front has a butterfly flap hung eccentrically, and so placed that
when exposed to a pressure from the inside of the stove, it flies
open automatically as soon as the catch holding it in closed
position is disengaged.   Cold blast is admitted to the central
flue in front of the instantaneous valve, as shown in Fig. 5.

The gas supply, governed by a mushroom valve, passes along
passages parallel with the combustion chamber, and enters therein
through the lower series of graduated openings shown in Figs. 1,
2, and 4.   The air supply is regulated by two valves at opposite
sides of the stove, and enters the combustion chamber through
the upper series of graduated openings.   In the majority of cases
these air-regulating valves are situated on the same side, but

nearer the base of the stove than shown on the diagrams, and on opposite sides of the combustion chamber, vertical air passages being provided in the brick lining.

After passing through the auxiliary regenerative chamber, the current of heated gases is distributed over and flows downwards through the main regenerative chequer-work, passing from thence through the internal valves to the chimney flue. The tops of the walls are canted, and the stay-bricks are designed and set in such a manner as to present no horizontal surface on which dust brought in by the furnace gases may accumulate. In addition to this, dust is as far as possible expelled by a strong current of air, to effect which, at each change from blast to gas, the stove being then filled with air at blast pressure, three of the internal valves, the hot-blast valve, cold-blast valve, air valves, and instantaneous valve are closed, the chimney valve is raised, the catch holding the eccentrically hung flap of the instantaneous valve in closed position is released, and the pressure on unequal areas causing it to open, the blast is suddenly discharged to the chimney flue, the whole of the imprisoned air passing through one regenerative compartment, the valve leading to which has been left open, and carrying with it all the dust deposited on the brickwork during the time gas was on the stove. The rush of blast in this last compartment is downwards, and in the remaining three upwards. At the following change from blast to gas another compartment is dealt with, and so on in systematic rotation, every compartment getting a downward rush of blast when its special cleaning time arrives, and an upward rush when the other compartments are being cleaned. This alternation is of great importance and practical benefit in the cleaning process.*

Where the gases are very dirty, it is usual and advisable to clean all four compartments consecutively at every change from blast to gas; the time occupied is only four minutes. Sluice valves are provided at the bottom of the gas passage and combustion chamber to admit of the dust collecting therein being periodically blown out.

This method of cleaning by discharge of the whole of the air under pressure in the stove, through the comparatively limited

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* The force of discharge is also increased by the partial vacuum in the chimney flue, and the increased pressure due to the expansion of the imprisoned air.

area of one regenerative compartment, has proved very effectual, and several stoves in connection with hæmatite furnaces using coke fuel have worked continuously for about five years since their erection, and are still at work without once having been laid off for cleaning.

The first stoves erected at Distington Ironworks have been in use for upwards of twelve years without costing one penny for brickwork repairs to the internal structure.

Notwithstanding the precautions which are taken to prevent accumulation of dust, it would be a mistake to suppose that the Ford and Moncur stove never requires to be stopped for cleaning; no such perfection has been attained, but it is an established fact that by careful attention to the simple and efficacious method of self-cleaning, these stoves may be run continuously without appreciable loss of power for the ordinary life of a blast-furnace lining. When laid off, it is as simple to brush the sides of the stay-bricks as it is to cleanse in the same manner the vertical passages of any other type of stove. Each regenerative compartment is divided into sixteen sections by walls $2\frac{1}{4}$ inches thick, in the greater number of which there are at least five openings of about 50 square inches sectional area each at the narrowest place between the top rows of stays. The blast or gas can enter by any one of these openings throughout the whole section; thus no appreciable difference is made to the working of a stove by a passage or two becoming choked so long as there remains a free inlet to each section, which is practically insured by the cleaning process.

The hot-blast valve shown is a cast iron disc, with hollow cast iron seat through which a current of air circulates from the cold-blast main. Valves of this class work efficiently for considerable periods and have been usually adopted with the Ford and Moncur stoves in preference to those with water-cooled seats.

At Sir Alfred Hickman's Springvale Furnaces a difficulty has been experienced owing to the brick arches carrying the division walls of the auxiliary regenerator burning away, and allowing the parallel side walls of the chamber to close in. To obviate this, the manager, Mr. Moore, has introduced a combination of the Cowper and Ford and Moncur constructions.

This important modification consists of a stove having four regenerative compartments, A, B, C, D (see sketch), separated by the partition walls E, and filled with Ford and Moncur chequerwork. The combustion chamber is of the Cowper type, 6 feet diameter, placed as shown. At the base of the stove are four internal regulating and cleaning valves, similar to those shown in the diagrams. This modification is worked in conjunction with Cowper stoves, having tile-filling $2\frac{1}{4}$ inches thick, 6-inch square
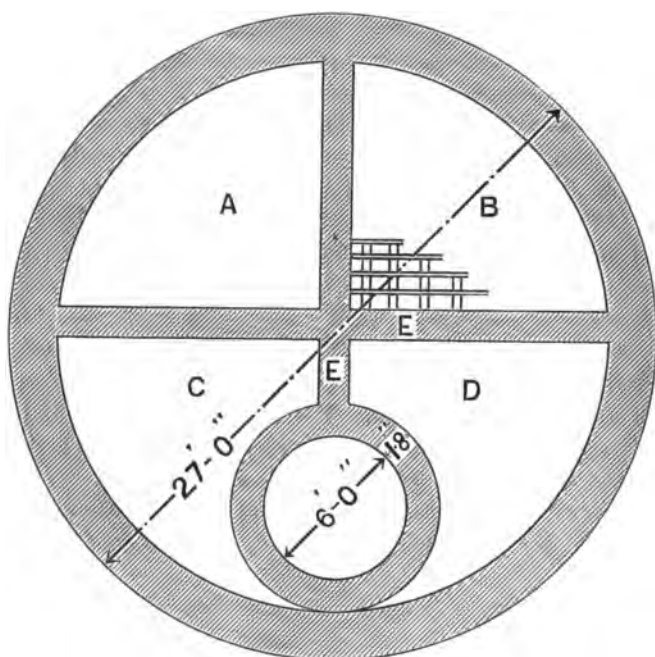
apertures; they are kept on gas for two hours, and on blast for one hour; the temperature at commencement of the blow is from 1350° to 1400° F., and about 1310° F. at finish. An internal examination is made once a year. No difficulty is experienced with the internal valves or the Ford and Moncur chequer-work, and Mr. Moore finds that two stoves of the modified construction are, in their general working capacity, after equal periods of work, equal to three other stoves of the same diameter and height.

These were among the first erected under the patent, and have only recently been altered. It is fair to say that this is the only instance of failure of the combustion chamber brickwork which has come under the writer's notice, and this may possibly be accounted for by an unsuitable material having been used. In the writer's opinion, the rectangular combustion chamber gives the best distribution of gases over the chequerwork. An arrangement with circular flame flue in the centre of the regenerative compartments is shown in the drawings accompanying the patent specification, and the Springvale modification is covered by the patent.

In order to give an idea of the trend of modern practice, and not as an indication of the comparative merits of the various systems, the writer has prepared a table of firms using hot blast:—

NUMBERS AND TYPES OF HOT-BLAST STOVES IN USE AT VARIOUS IRONWORKS IN GREAT BRITAIN.

Name of Firm.	County.	Number of Blast Furnaces.	Cowper.		Whitwell.		Ford & Moncur.		Massicks & Crooke.		Pipe.		Remarks.
			Working.	Idle.	Working.	Idle.	Working.	Idle.	Working.	Idle.	Working.	Idle.	
Whitehaven Hæmatite Iron Co., Ltd.	Cumberland	4	...	...	...	...	9	...	...	...	...	...	
Chas. Cammell & Co., Ltd., Workington	,,	5	...	...	...	...	8	...	...	...	...	...	
Chas. Cammell & Co., Ltd., Maryport	,,	2	...	...	...	...	...	2*	...	...	...	...	* In course of alteration; originally Whitwell.
Distington Hæmatite Iron Co., Ltd.	,,	3	...	...	...	...	5	...	...	...	...	...	Including the first erected. Temperature 1350° F.
Sir James Bain & Co.	,,	4	6	1*	...	...	...	...	...	...	...	...	13 years old, fitted with self-cleaning arrangement. *Off for repairs.
Lonsdale Hæmatite Iron Co., Ltd.	,,	3	...	...	...	...	4	...	...	...	...	...	
Lowther Hæmatite Iron Co., Ltd.	,,	3	...	...	...	8	...	...	...	...	...	...	Idle for some years.
Kirk Bros. & Co.	,,	1	...	...	3	...	...	...	...	...	...	...	
Millom & Askam Hæmatite Iron Co., Ltd., Millom	,,	6	...	...	...	...	8	...	...	...	...	...	These have been substituted for six Massicks' and four Whitwell's stoves.
Maryport Ironworks	,,	5	...	...	...	...	...	4	...	...	...	...	Idle for some years.
Moss Bay Hæmatite Iron & Steel Co., Ltd.	,,	3	...	...	...	...	4	1*	...	...	...	...	* In course of erection. 1400 F.
West Cumberland Iron & Steel Co., Ltd.	,,	6	...	...	...	...	...	...	...	...	...	...	Idle for some years. Also ten of Mr. Snelus's stoves.
Workington Hæmatite Iron & Steel Co., Ltd.	,,	3	...	...	...	...	...	...	13	...	...	...	Six 10 years old, seven 8 years old. Doing good work; temperature from 1200° to 1500° F., regular.
Brymbo Steel Co., Ltd.	Denbighshire	2	8	...	...	...	...	...	...	...	...	...	Cowper modified, 2 years old.

Company	County									Remarks
James Sparrow & Son	Derbyshire	2	…	…	…	…	…	…	…	7½ years old.
Butterley Co., Ltd.	"	5	…	…	…	…	…	…	…	Incomplete return.
Clay Cross Co.	"	3	…	…	…	…	…	7	2	24 years old.
Denby Iron & Coal Co., Ltd.	"	4	…	…	…	…	…	5	4	15 years old, twenty-two 12-in. pipes in each. Work well, and no trouble with them.
Renishaw Iron Co.	"	3	…	…	…	…	…	7	…	Comparatively new; very satisfactory.
Wingerworth Iron Co.	"	3	…	…	…	2	…	…	11	Gjers, 20 years old; idle since April 1893.
Carlton Iron Co., Ltd.	Durham	3	…	8	4	4	…	…	…	Originally Whitwell, considerably modified. Four 22 years old and eight 24 years old.
Bell Bros., Ltd.	"	12	28	…	16	…	…	…	…	21 ft. diameter, 61 ft. 6 in. to springing of dome. Honeycomb filling 7-inch opening. 1888 to 1894.
Consett Iron Co., Ltd.	"	7	9	…	16	…	…	…	…	12 years old.
Joseph Torbock	"	2	…	…	…	…	…	…	22	63 ft. by 22 ft.; 4 to 6 years old.
Weardale Iron & Coal Co., Ltd.	"	2	4	…	…	…	…	…	…	
Darwen & Moatyn Iron Co., Ltd, Moatyn	Flintshire	3	…	1*	1	3*	3	…	…	*In course of erection. 7 to 8 years old.
Briton Ferry Works, Ltd.	Glamorganshire	2	4	1*	…	…	…	…	…	*In course of erection. 14 years old.
Dowlais Iron Co., Cardiff	"	…	8	3	…	…	…	…	…	5 years old.
Swansea Hæmatite Iron Co., Ltd.	"	2	4	…	…	…	1	7	…	Cowper's 20 years old, Ford & Moncur's 6 years old.
Millom & Askam Hæmatite Iron Co., Ltd., Askam	Lancashire	4	…	…	…	4*	…	…	…	*Eight Massicks & Crooke's stoves are being replaced by four Ford & Moncur's, in course of erection.
Barrow Hæmatite Steel Co., Ltd.	"	14	11	2	2	…	10	4	…	From 2 to 10 years old, including some of the earliest Ford & Moncur's stoves.
Carnforth Hæmatite Iron & Steel Co., Ltd.	"	6	…	…	…	…	4	…	…	Incomplete return.

NUMBERS AND TYPES OF HOT-BLAST STOVES—*Continued.*

Name of Firm.	County.	Number of Blast Furnaces.	Cowper.		Whitwell.		Ford & Moncur.		Massicks & Crooke.		Pipe.		Remarks.
			Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	
Darwen & Mostyn Iron Co., Ltd.	Lancashire	2	...	...	1	...	8	...	...	...	...	...	7 to 8 years old.
Wigan Coal & Iron Co., Ltd.	,,	10	...	...	16	7	...	...	...	...	...	...	15 to 22 years old. All working satisfactorily.
North Lonsdale Iron & Steel Co., Ltd.	,,	4	...	...	...	...	6	...	...	...	...	...	
Holywell Iron Co., Ltd.	Leicestershire	4	6	...	...	...	...	...	2	...	...	...	Four Cowper's, 14 years old, one 5 years old, one 3 years old; one Massicks' 1 year old; and one Massicks' new.
Appleby Iron Co., Ltd.	Lincolnshire	8	...	...	6	...	...	...	6	...	...	...	18 months old.
Frodingham Iron & Steel Co.	,,	4	...	...	...	...	...	...	...	2*	...	...	* In course of erection. Three 13 years old, three 5 years old.
Redbourn Hill Iron & Coal Co., Ltd.	,,	2	...	...	...	...	...	...	...	...	6	...	22 years old.
Blaenavon Co., Ltd.	,,	9	...	...	...	...	1	...	...	...	...	...	Incomplete return.
North Lincolnshire Iron Co., Ltd.	,,	4	...	...	...	...	...	...	12	...	...	...	Three put to work in March 1896. Nine 2 to 4 years old.
Trent Ironworks	,,	6	3	...	...	...	...	...	...	...	8	...	6 months old.
Patent Nut & Bolt Co., Ltd.	Monmouth-shire	1	...	...	...	...	...	...	...	...	...	...	6 months old.
Ebbw Vale Steel, Iron, & Coal Co., Ltd.	,,	4	15	...	...	...	...	...	...	...	...	...	8 to 25 years old.
Tredegar Iron & Coal Co., Ltd.	,,	5	...	11	...	...	...	...	...	...	...	...	
New Cransley Iron & Steel Co., Ltd.	Northampton-shire	2	5	...	...	...	...	...	...	...	...	...	2 to 4 years old.

Name	Locality												Remarks
Lalip Iron Co.	,,	4	5	1*	:	:	:	:	:	:	12	:	In course of erection. Two 10 years old, remainder recent.
Hunsbury Hill	,,	2	3*	1	:	:	:	:	:	:	:	:	6 years old.
Wellingborough Iron Co., Ltd.	,,	2	:	:	:	:	:	:	:	:	:	:	One Cowper-Kennedy. Two 7 years old, one 5 years old, one new.
Lilleshall Co., Ltd.	Shropshire	4	4	3	:	:	:	:	:	:	:	:	2 to 5 years old, all in order. 1890.
Midland Coal, Coke, & Iron Co., Ltd.	N. Staffordshire	6	:	:	:	:	:	:	:	:	:	:	
Chatterley Whitfield Collieries Co., Ltd.	,,	3	:	:	:	3	:	:	:	:	:	:	3 years old.
Stafford Coal & Iron Co., Ltd.	,,	3	4	:	:	:	:	:	:	:	:	:	13 years old.
Shelton Iron, Steel, & Coal Co., Ltd.	,,	6	8	:	:	:	:	:	:	:	:	:	Various ages.
T. & I. Bradley & Sons, Capponfield	,,	2	3	:	:	:	:	:	:	:	3	:	
T. & I. Bradley & Sons, Darlaston	,,	2	:	:	:	:	:	:	:	:	:	:	
Corngreave's Furnace Co.	S. Staffordshire	5	2	1	:	:	:	:	:	:	:	:	5 years old; working very satisfactorily.
G. & R. Thomas	,,	2	:	:	:	:	:	:	6	:	6	:	10 to 20 years old. New pipes have been put in when required.
Sir Alfred Hickman	,,	6	7	:	:	1*	4	:	:	:	:	:	In course of modification. Ford & Moncur modified.
Roberts & Co.	,,	4	5	:	:	:	:	:	:	:	:	:	Two 1889, one 1891, one 1892, one 1893. Honeycomb filling.
Willingworth Iron Co.	,,	2	3	:	:	:	:	:	:	:	:	:	3 years old.
Joseph H. Pearson	Worcestershire	2	3	:	:	:	:	:	:	:	:	:	About 3 years old.
Cochrane & Co.	,,	2	3	:	:	:	:	:	:	:	:	:	Two about 20 years old, one about 5 years old.
Acklam Iron Co., Ltd.	Yorkshire, N. Riding	4	12	:	:	:	:	:	:	:	:	:	8 years old.

NUMBERS AND TYPES OF HOT-BLAST STOVES—*Continued.*

Name of Firm.	County.	Number of Blast Furnaces.	Cowper.		Whitwell.		Ford & Moncur.		Massicks & Crooke.		Pipe.		Remarks.
			Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	Work-ing.	Idle.	
Gjers, Mills & Co.	Yorkshire, N. Riding	4	...	...	...	...	...	...	...	...	24	...	Cast iron, Gjers' pattern; 26 years old; working satisfactorily. 8 to 10 years old.
Cargo Fleet Iron Co., Ltd.	,,	5	10	...	...	...	...	...	...	...	...	...	
Bolckow, Vaughan & Co., Ltd., Cleveland	,,	8	13	...	...	...	...	...	...	...	...	...	
Bolckow, Vaughan & Co., Ltd., Eston	,,	3	8	...	...	...	...	...	...	...	...	...	Ages 2 to 15 years.
Bolckow, Vaughan & Co., Ltd., Lackenby	,,	3	6	...	...	...	...	...	...	...	...	...	
Bolckow, Vaughan & Co., Ltd., Middlesbrough	,,	2	6	...	...	...	...	...	...	...	...	...	
Bolckow, Vaughan & Co., Ltd., South Bank	,,	8	15	...	...	...	...	...	...	...	...	...	
Sir B. Samuelson & Co., Ltd.	,,	8	17	...	...	...	...	1*	...	...	...	...	* In course of erection. About 14 years old; chequers 5 in. square opening. One hour blast 1300° to 1200°.
Normanby Ironworks Co., Ltd.	,,	3	6	...	...	...	...	2*	...	...	...	...	* In course of erection.
Cochrane & Co., Ltd.	,,	4	12	1*	...	...	...	...	...	...	...	...	* Siemens, Cowper, Cochrane. From 1 to 30 years old.
Wilson, Pease & Co.	,,	5	10	2*	...	...	...	...	...	...	...	...	* Spare stoves. From 6 to 8 years old.
William Whitwell & Co., Ltd.	,,	3	...	...	9	5	...	...	...	...	...	...	Five 23 years old, four 20 years old.
John Brown & Co., Ltd.	Yorkshire, W. Riding	3	8	2	...	...	...	...	...	...	...	...	15 years old.

Works	County							Remarks
Leeds Steel Works, Ltd.	„	8	5	1*				* In course of erection. 6 years old; working satisfactorily. 20 years old.
Newton, Chamber & Co., Ltd.	„	2					9	
Wm. Cooke & Co., Ltd.	„	2				2	5	About 3 years old.
West Yorkshire Iron & Coal Co., Ltd.	„	5	4			12		Cowper's, 4 to 14 years old. U pipe 25 years old.
Glengarnock Iron & Steel Co., Ltd.	Ayrshire	11			14			Nine 12 years old, five 8 years old. Very good stoves; give no trouble.
Dalmellington Iron Co., Ltd.	„	6			5			Two 9½ years old, two 7½ years old, one 2½ years old.
Wm. Baird & Co., Ltd.	Lanarkshire	29			18			
Wm Dixon, Ltd.	„	11		3*	7			* Two Whitwell, being altered to Ford & Moncur; a new stove in course of erection.
Merry & Cunninghame, Ltd.	„	5		13				8 to 15 years old.
Coltness Iron Co., Ltd.	„	11			8			
Shotts Iron Co.	„	6			3			
Summerlee & Mossend Iron & Steel Co.	„	7			5			3 years old.
Glasgow Iron & Steel Co., Ltd.	„	4			3			72 ft. by 26 ft.
Carron Co.	Stirlingshire	4	4	1				Regenerators 5 inches square. From 5 to 11 years old. The Ford & Moncur cleaning arrangement is used with these stoves.
Total		·	318	110	142	64	151	
In course of erection		·	3	3	13	2		

Note.—Discarded stoves have not been included.

In this will be found the numbers and types of heating apparatus in use at a large number of works in Great Britain. The writer regrets that this table is incomplete, but trusts it may be of interest and of service as it stands.

An examination of the table will show that in twenty-nine instances where Cowper stoves are used exclusively, 128 furnaces are provided with 241 stoves, or 1·88 per furnace. Although none of these are returned as discarded, many are old and of small capacity. Neglecting these, and taking fourteen instances · where Cowper stoves of recent date are used exclusively, 47 furnaces are provided with 68 stoves, or 1·4 per furnace.

In seven instances where Whitwell stoves are used exclusively, 31 furnaces are provided with 91 stoves, or 2·9 per furnace.

In four instances where Massicks and Crooke stoves are used exclusively, 12 furnaces are provided with 35 stoves, or 2·9 per furnace.

In eight instances where Ford and Moncur stoves are used exclusively, 45 furnaces are provided with 48 stoves, or 1·07 per furnace.

These deductions are approximate only; it has been found impossible to distinguish between furnaces working and idle, and between those provided with an insufficiency or superabundance of heating apparatus. In addition, probably from 40 to 50 Ford and Moncur stoves are under six years of age, and the greater portion of large dimensions. Where the gases are clean, the working results of modern Cowper and Ford and Moncur of similar size are about the same, three stoves being found sufficient for two furnaces. The advantage which the Ford and Moncur construction possesses is that whilst it is unnecessary to provide spare stoves, this provision must be made where Cowper stoves are fired with dirty gases, and further, the gases are better distributed over the Ford and Moncur chequer-work, and the brick surface is more easily kept clean.

The writer calculates the heating surface of the stove illustrated as follows :—

	Square Feet.
Combustion chamber and auxiliary regenerator . . .	7,320
Four main regenerative compartments and passages . .	58,680
Total	66,000

The cost of such a stove, erected complete, with internal brick

PLATE I.

A

B

26

HOT BLAST VALVE

D

AIR VALVE

C

E

F

CLEANING VALVES

G

H

CHIMNEY VALVE

M.
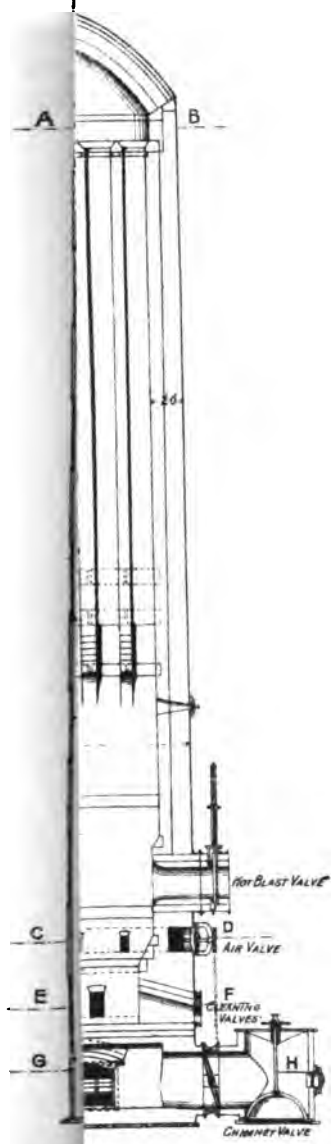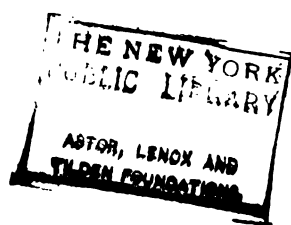
structure and all mountings, but exclusive of foundations and connections, is about £1600.

In conclusion, the writer desires to express his thanks to the numerous firms which have supplied information regarding their stove plants ; to Mr. Crawford of Moss Bay Iron and Steel Co. ; to Mr. Moncur of the Distington Iron Co. ; and to Mr. Marley of the Workington Bridge and Boiler Co.

DISCUSSION.

Mr. W. WHITWELL, Hon. Treasurer, said the paper would be highly appreciated by many interested in blast-furnace practice. He had thought it desirable, and only a duty towards his late brother, Thomas Whitwell, the original patentee of his firebrick system of stoves, to bring before the Institute a few details, which he would endeavour to do from a perfectly independent point of view, and not with any desire to compete in any degree with the improvements which had been shown in many modified systems of firebrick stoves which had followed upon the original Whitwell. He was struck with the much larger diameter of the Ford and Moncur stove, namely, 26 feet, which was much greater than the standard diameter of stoves of the Whitwell, Cowper, and Massicks and Crooke's style, which were 22 feet, 21 feet, and 22 feet respectively in diameter, the comparison of the areas being as follows :—

	Square feet.
The Whitwell, with 22 feet diameter, had an area of . .	380
The Cowper, with 21 feet diameter, had an area of . .	346
The Massicks & Crooke, with 22 feet diameter, had an area of	381
The Ford & Moncur, with 26 feet diameter, had an area of .	531

It would thus be seen that the Ford and Moncur stove had about 40 per cent. more area than the Whitwell. The Ford and Moncur stove with a diameter of 26 feet and a height of 72 feet contained, he believed, 38,232 cubic feet, and was said to have 66,000 square feet of heating surface; but this very large heating surface figure he very much questioned, as it could not be all effective, or nearly so. When it was taken into consideration that a Whitwell stove, 22 feet in diameter and 72 feet high, contained only 28,000 square feet of effective heating surface, and that if a stove of the Whitwell design in regard to internal brickwork were built of the same size as the Ford and Moncur, namely, 72 feet by 26 feet, it would only contain about 41,000 square feet of effective heating surface, it would be apparent that this abnormal surface must be taken *cum grano salis.* The exposed surface of brickwork might be there, but it was somewhat crowded together with very small openings, so

that the dust would stop them up and reduce the effective heating surface very materially.

On page 32 it was stated that the number of Ford and Moncur stoves applied exclusively to 45 furnaces gave a proportion of 1·07 per furnace, while that of the Whitwell gave 2·9 per furnace. He would say that many of these Whitwell stoves that were enumerated were of the old patent originally arranged by his late brother, and only 28 feet in height. The patent, which he, as executor, took out some years after his brother's death, and which was used largely and almost exclusively, now gave an increase of height to the stove, and had different wall arrangements. The proportion given for the Cowper stove was 1·4 per furnace, and for the Massicks and Crooke stove 2·9. Here again the extra size of the Ford and Moncur stove must be remembered, and the fact considered, as to whether the furnaces to which these stoves are attached are not under power with regard to stove ability. The system of cleaning, namely, by filling the above with air-blast pressure, and blowing out each compartment consecutively might be efficacious, but it was open to some doubt, and he was sure that the dust would cling and lodge in such a way as not to be properly removed in this manner, and that the heating surface would therefore be somewhat decreased.

The author estimated the cost of a Ford and Moncur stove to be about £1600 complete with all ironwork, valves, and brickwork, but without foundations; whereas the cost of the Whitwell stove, 22 feet by 70 feet—that was the new modified stove which was 40 per cent. less in capacity—was about £1550; that was the lowest price at which it could be properly and satisfactorily erected. This difference of cost could easily be accounted for when the design and durability of the Whitwell valves was contrasted with the valves of the Ford and Moncur stove, the latter being liable to leakage trouble. The Whitwell valves were the old original valves of his late brother, many of which had been at work persistently for the last 20 or 22 years without any repairs or change, and that was a very satisfactory element in connection with them.

Since his brother's death the development of the use of the Whitwell stove had been enormous, because the patent

having been purchased in America the American stoves were modified as between a Whitwell system and a Cowper system in a more or less degree.   He believed there was now being made with a stove of this kind—either of the original Whitwell type or of the modified form which had been adopted in many countries—about six million tons of pig iron per annum.   He did not wish to say one word in reference to his late brother, except that it was his delight to develop the system which he in a great degree initiated.   It had been his own pleasure, and indeed his duty, as executor, to improve upon his brother's arrangements and to develop them for the benefit of those who claimed and were entitled to any earnings after his lamented death.   The success which had attended the firebrick system had naturally been admitted by all pig iron makers, and he was very glad that those who were connected with him—his brother had had the privilege, for instance, of having Mr. Ford for many years under his leadership at Thornaby—had gone out into the world and had done good work.   He quite appreciated the good work that had been done by the Ford and Moncur stove, and he had not a word to say against it.

Mr. C. E. COWPER said that as representing the interests of the Cowper stove, he naturally had listened with very careful attention to the paper, which so very clearly described one of the latest modifications of the firebrick stove.   Mr. Whitwell had fallen into an error in speaking of the stove of the late Mr. Thomas Whitwell as the first firebrick stove.   That was altogether a mistake.   The Cowper stove was the first firebrick stove; and if anything were required to prove that, he might mention that Mr. Thomas Whitwell at first worked under a license from the late Mr. E. A. Cowper when he produced his modification of the firebrick stove.   A number of modifications had been introduced by several different inventors.   The Cowper stove (with which Mr. Charles Cochrane and the late Sir William Siemens had also been associated) had passed through a number of stages, the tendency being not only to gradually increase the height of the stove, but also to increase the size of the passages and to make them straighter and smoother.   They commenced strongly influenced by the Siemens regenerative furnace, which

originally suggested the idea of the regenerative stove. The regenerators of the Siemens furnace were of small height, and it was considered necessary to break up the current. For this purpose the bricks were so placed as to force the current to take a zigzag course. They at first adopted the same principle in the stoves, but gradually made the passages less and less zigzag, and finally smooth and straight.

The latest improvement had been to get rid of the square corners, for when dust tended to adhere, it would hang much more to a square corner. He had exhibited two or three samples of the latest form of regenerator brick, called the "honeycomb." In that brick the passage was a hexagon, and there were no square corners. The walls were only two inches thick, and yet the brick was very strong. With regard to the cleaning, they found as a rule there was no necessity to have spare stoves to lay off. The stoves would work for years without stopping for cleaning or repairs. The stoves were easily cleaned by blowing out, and, if necessary, the concussion caused by the discharge of a gun was utilised for the purpose of bringing down the dust. It was simply a luxury to have an extra stove. With regard to the straight walls in the Ford and Moncur stove, dividing the regenerator into different compartments, he would point out that each of those walls involved a loss of area in the regenerator, that is, a reduction in the heating power of a stove of a given diameter.

With regard to the proportion of stoves to furnaces, the author, after first giving a comparison very much against the Cowper stoves, very fairly remarked that many of those stoves were old and of small diameter and small height, and consequently more were required per furnace. These stoves had been made, to suit different circumstances, of all diameters from 15 to 30 feet. In arranging the stoves for old works they seldom found two cases alike. In some works they could introduce a few large stoves of 25 or 30 feet diameter; but in many cases that was absolutely impossible, and a larger number of small stoves had to be employed. Of course, in laying out new works, the stoves could be made of any desired size, and the tendency in modern works was to give much more space round about the furnaces. However, they had never found a single case in which the stoves

could not be introduced. In the early days of firebrick **stoves** they had considerable opposition, and the term "superheating" was introduced when firebrick stoves were discussed. When the blast was heated to a red-hot temperature it was spoken of **as** "superheated," as though the additional heat were something altogether unnecessary. That expression was not now so **often** employed. The paper had called attention to the fact that **there** were still some works which had the antiquated pipe stoves, **and** he hoped that the reading and discussion of the paper **would** have some influence in inducing the owners of these **works to** discontinue the wasteful use of extra coke which had to be **burnt** to make up for the deficiency of heat in the blast. He hoped **it** would not be very long before the last pipe stove would be **sent** to the South Kensington Museum as a curiosity.

Mr. J. ADAMSON said that, seeing that the Company **that** he was connected with happened to be as great an offender in the number of stoves as any of them, he thought **he** ought in fairness to the patentee, and to all connected with the management, to defend their position. The author gave the number of stoves as three; that was true, though they could and did work with two when it was necessary. In North Lincolnshire the furnaces were worked "isolated," and therefore each furnace, whether in or out, required a full complement of stoves; and, further, by the exigencies of the position, they could not get large diameters. The only thing they could do was to put the stoves in the room they had with the old pipe stoves, and judging by the cost, and by what Mr. Whitwell had told them, they had practically got the stoves for the same money as far as cost was concerned, which was a thing quite beside the question as to effect. They put three stoves to each furnace, to be quite sure that if there was any collapse of a combustion chamber or anything else, they would have stoves to work with.

Reference had been made to the West Coast, but if the speaker came to Frodingham he could assure him that a whirlwind was required for a furnace,—practically, for every ton of iron made they required twice as much blast as on the West Coast. If that was the case, as he had every reason to believe it was, they required very much more surface than on the West Coast to

beat the air to the required temperature. The temperatures which had been mentioned made his (Mr. Adamson's) mouth water. They could have more if they could work anything like 1400°. They could get it, but the furnaces did not require it. Any temperature they required they could get, as there was ample power.

Reference had been made to the origin of the brick stove, and no member of the Institute had greater admiration than himself for the late Mr. Thomas Whitwell. Mr. Thomas Whitwell had told him the idea of the brick stove was given to him by a paper read on refrigerators, and he was called upon as President of the Institute of the Cleveland Engineers to make some remarks on a paper read by Mr. Morton on the "Reduction of Temperatures." He had all his time been trying to raise temperatures, but then he adopted practically the idea of a refrigerator in a firebrick stove.

He (Mr. Adamson) wished members to clearly understand that even in an outlandish place like Frodingham they had some reason for doing what they were doing in putting a large number of stoves down.

Mr. CHARLES WOOD said that at one time he had a large quantity of iron stoves, but he had discarded them many years ago. He was one of the first to put up brick stoves after they came into practical use. There were many points about the brick stove shown on the diagrams which required a little closer examination. In the first place, he considered that the chief advantage of the stove lay in its capacity. It was, he thought, the large capacity and the large passages which really constituted the advantages of this stove. Many years ago he had recognised the necessity of larger passages, but at that time Mr. Cowper thought that if the passages were enlarged the stove would be robbed of heating surface. He put in very much larger regenerators than was advised by Mr. Cowper, but the success of these stoves over those Mr. Cowper had had previously in use was so great that he reluctantly agreed, after some experience, that it was an advantage. He (Mr. Wood) afterwards again considerably increased the capacity; in fact from the passages being 4½ in. square he got them up to

7 in. It was then said, "Oh, well, you will destroy the stove altogether now." He took the opportunity of passing a piece of bright wire up the passages from the bottom to the top of the stove, after the stove had been heated ready to go on, and to his surprise he found that the top third of the wire was thoroughly oxidised, burnt in the same manner as it would have been if it had been put into the fire; the next third had evidently been partly red hot, whereas the bottom third was scarcely blue. That was after the stove had been heated ready to put on, and the temperature of that stove when put on to blast was between 1500° and 1600°. ♪ That proved that he was not robbing the heating surface.

In the stoves that had the very largest passages, when the stoves were being heated the gases passed more freely through and heated quicker. The heat descended rather lower down, but really the temperature passing off at the chimney was very nearly the same. Also they were able to work the stove with the larger passages a very much longer time before shooting or blowing out, the stoves gave very much better heat, and required cleaning much less often than anything with small passages. It would be seen that in the diagrams given by the author there were a series of very large passages. The author had gone even further than this, and increased his whole stove, and as Mr. Whitwell had pointed out, to double that of the Cowper stoves, and he (Mr. Wood) might say to three or four times the capacity of some of the old Whitwell stoves. If the members would take this into consideration, and compare the table which the author had published in his paper, he thought they would agree that that table had almost better never have been published, because it was so entirely misleading. It was not fair to compare a stove of the area and height and capacity shown with stoves that were put up ten, twelve, or fifteen years ago; and to publish such a comparison was very misleading.

He did not altogether dislike the central flat chamber forming the combustion chamber; there might be some advantage in that. He did not think there was any use at all in dividing the stoves off into squares, because with a stove of such enormous capacity it really did not matter whether the blast was passed down one division or the other. With regard to the valves at the

bottom, the author stated that they were not much use. What was the good, therefore, of complicating a stove by putting them in ? They were far better left out. He might say that he had had Cowper stoves at work for six or seven years, working at 1500° or 1600° continuously, before ever a man went into them at all. It was only after about six years' constant work that they found the frame flue-bricks had burnt through into the regenerators, and after they were renewed the stoves went into work again.

Taking into consideration the size of these old stoves compared with the one shown by the author, the statement which he (Mr. Wood) had given of these stoves working continuously night and day, without ever a man going into them, for six or seven years, could not be equally made on behalf of the Ford and Moncur stove; but when they began to increase the whole size of the stove as they had from 20 feet and up to 27 feet diameter, with a height of nearly 75 feet, and adopt the central flat frame-flue, it became necessary to put the two cross walls up to support the two flat frame flue-walls, otherwise they would bulge out and collapse. At the same time he did not think that should be claimed as an advantage. It looked to him as if there might be some little advantage in the regenerators above and inside of the combustion chamber. It would be seen from Fig. 3 that the combustion chamber was divided into very large vertical divisions. They all knew that when gases were burnt in the combustion chamber the particles of dust in the gas held in suspension were really in a molten state, and those particles of molten dust were liable to attach themselves to the first obstruction they met. In the Cowper stove, where there was a large chamber, the flame passed up through the 6-feet chamber and turned over on to the regenerator, and the molten dust deposited itself on the first two or three layers of the regenerator on the top. The particles of molten dust, in passing up those very large vertical regenerators shown on the diagrams, might attach themselves to the vertical regenerators and consequently get deposited there, where they might do less harm, rather than on the top of the regenerators of the Cowper stoves. There might be some little advantage there.

Reference had been made by Mr. Cowper to the use of larger

passages, and he had produced some honeycomb bricks. He (Mr.
Wood) adopted the flat brick originally of very much larger section.
At Mr. Cowper's recommendation he had tried six stoves with the
honeycomb bricks having the same area as his original stoves.
He was bound to say he had been disappointed with them. In
the first place, the extra cost of the stove had been great, each
stove costing something like £150 ; and in the second place, he
found no advantages whatever.   In the last stoves he had built
he put in plain tiles, having passages about 7 inches square, and
they had given the best results of anything he had ever had,
and the cost of each stove had been something like £150 less.
If Mr. Cowper were to build his stove of the same height and
diameter, with 9-inch regenerative passages, he should prefer it,
on account of its simplicity and less cost, to the Ford and Moncur
stove.

Mr. E. G. Tosh said it was not his wish to take any promi-
nent part in the discussion, but as a user of the stoves in question
he should like to bear testimony in all fairness to what he con-
sidered their efficiency and value.   He commenced at Ulverston
by putting down three of those stoves 65 feet high by 26 inches
diameter, to one furnace, but he soon found that two were amply
sufficient.   He afterwards supplemented those three stoves by
three more, and he found that the six stoves were quite capable
of heating the blast for three furnaces to a temperature of 1300° F.
The average production of three furnaces was about 2400 tons
per week of iron.   With regard to the self-cleaning qualities
of the stove, to his mind these constituted its greatest recom-
mendation.   These firebrick stoves were the first which had
been erected at Ulverston, and the first which the staff had had
anything to do with.   They were in continuous use for five years
and a half, and when they came to be looked into at the end of
that time—not because there was any falling off in duty, but
because it was thought necessary as a working precaution to see
how things were going on inside—they found that with the
exception of the three or four courses of the checker work at the
top the stone was practically clean.
The blowing through of each quarter consecutively was an
admirable way of removing the dust.   The wholesale removal of

dust by the blowing-through operation was quite obvious to any one who cared to watch the chimney-tops after the instantaneous valve had been opened. The repairs were extremely light, but he should advise all adopting the stoves, as a matter of practice, to open them up periodically, so that each stove underwent examination every eighteen months or two years. In the generality of cases it would be found that only a small portion of the checker work required running through with a wire brush. The stoves would then be as good as ever. The valves had acted satisfactorily, and as far as he had been able to judge from ten years' practice, if he were going to fit up more stoves in the hæmatite district he should adopt the Ford and Moncur type.

The statistics which had unfortunately been given at the end of the paper were entirely misleading, and, as showing the relative values of various types of stoves, valueless. Taking the instance of the North Lonsdale Furnace, there appeared to be six stoves down for four furnaces, but there might be one furnace only in blast, which would be credited with six stoves, or three furnaces in blast as at present with the same number of stoves. As to the cost of the Ford and Moncur stoves, he would be quite frank and say that he thought the author of the paper had understated it. In the case of the six stoves which were put down by the North Lonsdale Iron and Steel Company, including a not large quantity of flue and foundation work, the actual cost was £13,200.

Mr. T. E. G. MARLEY said he thought it was necessary to intervene at that stage of the discussion—speaking on behalf of Ford and Moncur—so that he might refute certain remarks made and arguments used in connection therewith. The premises being altogether wrong, the conclusions arrived at were wrong also. He would first of all speak with regard to Mr. Wood's remarks. Mr. Wood mentioned the capacity of the stove, and alluded to the fact that those stoves were on account of their capacity so much better than other stoves. The stove on the diagram was 72 by 26, which was the size of the stove generally recommended, but it was by no means the size of the stove that had always been adopted. Ford and Moncur had stoves in many cases 18 feet in diameter, which they had altered from other patents.

He did not wish to say anything derogatory to other patents, he only wished to speak on behalf of the Ford and Moncur. In one works they had six stoves working 18 feet diameter, and they had some at 19, some at 20, and some at 22, &c. Therefore Mr. Wood's remarks with regard to the capacity of the stove immediately dropped through, because Ford and Moncur had stoves used at other places of very much smaller capacity than 72 feet by 26 feet. Then Mr. Wood also asked, why divide this stove into four compartments? and he said that the four bottom internal valves were no use. The whole system of the cleaning portion of the patent devolved upon the question of the four doors. If they did not put down the four doors at the bottom how were they going to blow the stoves out and make each quarter effective? It was by closing three of the internal valves, leaving open the fourth and opening the chimney valve, and getting the whole of the pressure through that one quarter of the stove—so getting the pressure through that quarter the openings in which are practically equal to the chimney valve area—that the dust question in the stoves was successfully combated. One case had been mentioned by Mr. Wood which he considered Messrs. Ford and Moncur would find it hard to beat, in which he says a stove was run six years. He could name several that had run longer. He thought the author had mentioned one case in his (Mr. Marley's) own district where a stove had run twelve years. As a matter of fact, that stove up to the present day had never been cleaned except by the self-cleaning process, a process which cost nothing whatever. As regarded Mr. Wood's remarks with regard to the passages, there was no possibility of those passages getting stopped up at all, because they were open right across the regenerative chamber, and if one passage opening did happen to get stopped up, only about one square foot of heating surface would be damaged, and therefore it was practically of no moment; whereas with the octagon and the hexagon brick, and the other bricks, if the opening did get stopped up, as it did in certain cases, that heating surface was not available from top to bottom, but was utterly useless.

Then as regarded the size of the passages, they were generally about 5 inches by 5 inches. He pointed that out because

Mr. Wood had said they were very large. With regard to Mr. Whitwell's remarks as to the heating surface, he (Mr. Marley) believed that the author had understated it; but it was a question that Mr. Whitwell could easily ascertain for himself by ordinary calculation, so that it was not necessary to say anything further on that point. As regarded the effectiveness of the heating surface, the effectiveness was the main point of the stove, because the combustion chamber being in the centre and all the regenerative chambers communicating with the central flue at the bottom, there was not the slightest tendency for the gases to go direct to the chimney valve. If there were a tendency for one regenerative chamber to take more gas than another, that could be regulated by those four internal valves; but as a matter of fact it was not found so, and therefore they were never used with that object.

As to cost, Mr. Tosh had kindly mentioned the cost of his stoves at Ulverston, but he could speak, he believed, with perfect authority on that point, and say that £1600 was practically the cost. Of course it depended a great deal upon the brickwork in any district. He had a case in which the cost, exclusive of foundations and connections, but including all the valves, was as low as £1500, which was £100 below the actual amount stated in the paper. Therefore the author had not understated the cost. Mr. Tosh reminded him that in his (Mr. Tosh's) case he included the flue and the foundations, which the author expressly stated in his paper he did not include. With regard to the cost of the valves, Mr. Whitwell had said that their valves were more expensive than the Ford and Moncur. He knew the cost at which they could both be made, and as a matter of fact Ford and Moncur having to provide extra valves, in consequence of the extra valves they were more costly. As regarded the efficiency of the valve, there was no valve in connection with that stove but what might go on for twenty or thirty years, with the exception of the hot-blast valve, and that was one which he did not think anybody, speaking generally, had yet attained perfection in.

Mr. Wood said the heating capacity of a stove depended a very great deal on the power of the chimney, and also on the quantity and pressure of the blast passed through, and the

quality of the gases used, whether from hæmatite, Cleveland, or basic furnaces.

Mr. COWPER said he should like to add one word of explanation with regard to the cost of the stoves. There was in each pattern a certain capacity of iron-casing, fairly well filled up with brick-work, and with materials at the same prices there was not likely to be much difference between the cost of one type and another. Mr. Wood had been an early advocate of large passages, and very possibly had influenced them in making large passages in the honeycomb bricks. Although Mr. Wood preferred his own pattern, many firms had considered it quite worth while to take out the square bricks and replace them with the honeycombs.

Mr. W. ROBERTS said he wished to ask the question, how was the dust blown out from those stoves ? He did so, because at Sir Alfred Hickman's Springvale furnaces, which had been men-tioned, when they blew the dust out from the Ford and Moncur stoves into the flue or chimney they found that it blew along the flue and got underneath the boilers, choking up to a certain extent the flues underneath the cylindrical boilers. They had to make alterations and pits for the dust to fall in between the stove and the large chimney. He asked therefore for informa-tion, how the dust was got rid of in the 151 brick stoves which were mentioned in the paper? He thought that what occurred to all of them was that as they made stoves larger and increased the size, and naturally the efficiency, it became more difficult to blow out from one valve the dust from a large Cowper stove with a large quantity of checker-work, that is, if they increased the diameter of the stove from 18 or 20 to 26 or 27 feet, and thus the advantage of the Ford and Moncur stove being divided into four sections, having four different valves by which they could blow out the dust, became more apparent to all of them. It naturally followed that as the diameter was increased so the efficiency was increased, whatever stoves were used.

That was not the occasion to waste the time of the Institute by a " battle of the stoves " as a whole, but they should rather discuss the paper itself which was before them. No doubt the writer of the paper very properly said the statistics which were

put at the end were not a guide ; he did not argue that they should be, and therefore they must not criticise the figures too much.   They naturally depended on a question of whether the furnaces were in blast, and they could not say whether they were in blast or whether they were not.   It happened that under the head of South Staffordshire (page 29) where the name of Roberts & Company appeared, and other names in other parts of South Staffordshire, there was shown a total of ten furnaces, out of which only five were in blast.   Sir Alfred Hickman, just above, had six, and four in blast.   The names following showed ten furnaces, of which only five were in blast.   They could not argue upon the statistics, because all the particulars were not before them.   He therefore repeated his question, how was the dust got rid of ?   Was it blown into the open air, as in the Cowper and other stoves, or must it be blown into the passage which went from the stoves to the stack—should it be blown outside as, for instance, in the Cowper stove ?

He would also ask another question and mention a fact, viz., that in that part of the combustion chamber sometimes called the " auxiliary combustion chamber "—where 26 was shown upon the Figure 1 (Plate I.)—destruction often took place.   There the combustion chamber began by a series of upright walls fastened upon arches, and there was no doubt the quicker they could bring hot brickwork to assist the combustion the better, if the brickwork could be maintained.   In the case of the Walsall furnaces belonging to Russel & Co., which were not mentioned in the list, their walls very quickly gave way.   The gas in South Staffordshire was full of dust which came from the white ash of the coal, in which there was lime, and it very quickly set upon any brickwork in contact with it, and very quickly assisted to melt or burn the brickwork.   Therefore these walls in the so-called auxiliary combustion chamber were rather difficult to maintain.   He took it they might be very well maintained by not merely having one arch two or three feet in height and above that a series of straight walls, but they might be maintained by having a series of arches from bottom to top, that when two or three happened to fall there should still be two or three continuous arches left, and no straight horizontal courses of brickwork at all from the bottom to the top underneath the

dome.   That difficulty might be very fairly got rid of, and if
it occurred to any gentleman who used the Ford and Moncur
stoves, he should be glad to have the information.   He asked
therefore the question, must the dust be blown into the flue,
or might it be blown outside ?   Did those walls fall to pieces
where the dust in the gas was of an alkaline or limey character ?
and could a series of arches be put in the place of a horizontal
wall so as to prevent that falling away ?   He asked this because
in the case of Walsall the walls had fallen away, and the stoves,
instead of going on for ten or twelve years, were comparatively
ruined in two years' time.

Mr. J. CRAWFORD (Moss Bay Iron & Steel Co.) said, with
regard to the Ford and Moncur stoves, he had had a good deal
to do with the Cowper stoves, and also with Whitwell's.
Latterly they had adopted the Ford and Moncur stoves at two
works with which he was connected, and, of course, one must
naturally be inclined to say something to show that they had
some faith in what they had put down.   When the Cowper
stoves were put down at the beginning two stoves were used
to one furnace.   They found in three months' time that they
could not keep up the heat of the furnace, and the result was
that a new stove had to be put down.   With the Cowper stoves
that they had the dust was blown out into the atmosphere,
making a mess of the whole place; when if one passage in
the Cowper stove was choked up at the top the whole passage
was then blank from top to bottom.   In the Ford and Moncur,
the regenerative work being crossways as well as vertical, if one
part did choke up the result was that the heat got back into the
other part of the stove.
There was one point which should be mentioned with regard
to these stoves, viz., the small amount of gas required to heat
them, which was a very important point where, at all events,
they had the works in which the whole of the gases could be
utilised for some purpose.   In that connection the Ford and
Moncur stove was of very great benefit indeed, as far as his
experience was worth anything.   The Whitwell was much smaller,
and the heat was so great that the chimney valves had to be
water cooled.

In the Cowper stoves as well as in the Ford and Moncur the iron grating was perfectly unprotected at the bottom, and the result was the heat was not going out at more than 500° at the chimney valves, so that the whole valuable effect of the gases was taken out. They, at all events, on the West Coast thought that the Ford and Moncur stove had many advantages over others. In a works with which he was acquainted there were eight stoves blowing five furnaces, making 4500 tons a week, and the average metallic iron in the ores was about 50 per cent., and the weight of limestone about 8 or 9 cwt. per ton of pig iron. That would be an argument for some of those gentlemen who said that the volume of blast was much less where those stoves were put down.

With regard to the blowing out of the stoves, they were always blown into a flue. If it was blown out into the atmosphere all the men round about would be disturbed in their work. If the flues from the stoves were connected with the main flue from the boiler the gases from the boiler would be blown back while the stove was being discharged. They found that if the flues were properly arranged and carried into the chimney, and a mid wall put up between the two openings, the boilers were never disturbed at all. It had been suggested by Mr. Tosh that a great volume of dust came right out of the top of the chimney. This was so, but of course there was still dust left in the flue to be taken out, but it was much better out than in the stove. As far as his experience went the stoves were effectually cleaned. After working five years he had the top taken off, and went into the combustion chamber and had a look to it, but he had never spent a single penny. The Whitehaven Hæmatite Iron and Steel Company (Limited) had done the same thing; they had never once cleaned their stoves, and had never been stopped for a single hour, nor paid a penny for repairs. The stoves had been working nearly eight years.

Mr. W. WHITWELL, Hon. Treasurer, had been much pleased to hear Mr. Cowper's remarks. He had not intended that there should have been any neglect on his part to give proper credit to the original patentee. He remembered his brother telling him over and over again that the original Siemens furnace had been

tried by Sir Lowthian Bell, and that the system at that time had
not been found to answer.   He had not forgotten the wondrous
energy introduced into the matter of the experiments by Mr.
Charles Cochrane, who was working, and had been working, so
long as he could remember Cleveland, with the Siemens stoves.
He quite admitted that his brother went to Mr. Siemens, if not
to Mr. Cowper's father also, to arrange with them for permission
to use their system when he brought out his patent.   He ad-
mitted, with full appreciation of the fact, that his brother did
pay royalty during the full time that he arranged to do so.

The CHAIRMAN said he might, perhaps, be permitted to say a
word or two.   Mr. Cowper had objected to the word "super-
heated."   It happened that he (the Chairman) was old enough
to remember that the cardinal point of heating-blast up to the
discovery of firebrick stoves was limited to 600°.   In fact, it was
supposed by ironmakers that the moment they passed the point
of 600° they were on dangerous ground.   He was himself, he
believed, answerable for the objectionable word "superheated."
It was thoroughly well known, he thought, that it was used
as a comparison of temperatures derived from the firebrick stove
with the old limit imposed upon heating-blast by ironmasters
anterior to the year 1870 or thereabouts.

With regard to the table, it had been admitted by the author
himself that it was somewhat misleading.   It would have been
much better, he thought, instead of talking of furnaces as was
done in the paper, if a calculation had been made of so many
thousand feet of stove surface to every thousand tons of pig
iron, or any other quantity made in a week or in any other
time.

Then, as Mr. Adamson pointed out, there was a great difference
in the quantity of blast required for smelting ore like that of
Lincolnshire and hæmatite ores; but the difference was not so
great as he seemed to imagine.   He was not going into the
details of the discussion that took place twenty or twenty-five
years ago, when he had to oppose single-handed, and to the best
of his ability, what he considered at that time, and considered
now, the extravagant expectations as to what could be effected
by the use of what he called superheated blast.   Some of the

advocates of superheated air made a kind of rule of three sum regarding the saving. Given a blast of 600°, what amount of fuel might they expect to save by increasing the temperature from 600° to 1200°?

There was no kind of justification for such a statement. The substitution of heat in the blast for that obtained from the solid fuel used in the furnace greatly reduced the volume of gases passing through the materials. That change greatly reduced the loss of heat carried away in the escaping gases. There was, however, a limit to that, due to the fact that as soon as one-third of the carbon in the gases was converted into carbon dioxide, their reducing power was greatly weakened. Numerous experiments satisfied him on that point, and he was led to assert, that in the manufacture of pig iron from Cleveland ore, it could not be hoped, in the long run, to produce it with less than 20 cwt. of coke per ton of metal. He believed that prophecy, made now twenty years ago or more, had been amply verified by the experience of Cleveland. In point of fact he might go further and say that the 20 cwt. was very rarely reached—he did not say it never was—as it was occasionally reached by himself even at the present time. But he was not quite sure that the museum at South Kensington would be enriched so soon as Mr. Cowper expected by placing in it the old metal stoves that were still in use. The fact was, that from some cause or another—speaking now exclusively of Cleveland ore—there was a very great inconvenience connected with the use of superheated air, viz., that a furnace which after going perfectly might suddenly commence what was called in Cleveland, and he supposed elsewhere, a process of "hanging." Only last week they had furnaces with 24,000 cubic feet capacity, which for a whole month required nearly 24 cwt. of coke, due to the cause just mentioned.

There was, however, one undoubted advantage connected with the use of superheated air, viz., the immense extra work that could be got out of a furnace. At the Clarence Works, the furnaces, which formerly worked with the blast at 1000° F., could now produce something like 700 tons more when blown with air at 1400° F.

Mr. B. J. HALL, in reply, said a good many questions had

been asked and a great many of them had been replied to in the course of the discussion. Owing to the limited time at his disposal, he would only deal with two matters. As to the calculation of area, he believed he was perfectly correct in saying it was 66,000 square feet, or he might perhaps have under-estimated ; he would be very pleased to go through the drawings and recalculate the area with any one doubting it. With regard to statistics, both in reading up for the paper and previously he had noticed in books on blast-furnace practice that very scant attention was paid to the Ford and Moncur stove, and as a prelimi-nary before presuming to offer the paper he wrote to all the blast-furnace owners in Great Britain asking them to send a return of the stoves they had in use. He wished to see how many Ford and Moncur stoves were really working, and the pro-portion between the Ford and Moncur and of other stoves. The tables were, he thought, valuable as showing as far as they went the trend of modern practice. He should have liked to have gone further into the question, but was not able, having neither time nor means to afford the great cost of a more detailed examination.

CORRESPONDENCE.

Messrs. MASSICKS and CROOKE stated that the Massicks and Crooke's stoves had of recent years assumed more formidable dimensions; it was not uncommon to build them 80 feet high. Notwithstanding this, the cost of construction was comparatively small. The work they were now doing in the Frodingham district in some cases was equal to blowing 10 tons of air (blow-ing cylinder capacity) per ton of iron made from a stone yielding only 25 per cent. of metallic iron.

The CHAIRMAN said he was sure their thanks were due to Mr. Hall for bringing this matter before the Institution. He begged leave to thank him on their behalf for the great pains he had taken with his paper.

The following paper was then read :—

THE PRODUCTION OF METALLIC BARS OF ANY SECTION BY EXTRUSION AT HIGH TEMPERATURES.

BY PERRY F. NURSEY.

So comprehensive are the developments of inventive genius in the present day, and so rapid and far-seeing are the strides made by invention, that they not unfrequently overtake, or rather overreach, the means at disposal for giving practicable form to otherwise practical ideas. Thus it sometimes happens that the introduction of an invention based upon common-sense lines is temporarily retarded, or the invention itself permanently lost to the world, and industrial progress in a given direction thereby checked, by reason of there being no adequate means or suitable materials at hand for bringing it to a successful issue.

A case in point is afforded by the carrying out in practice of the ingenious metallurgical process which I now have the privilege of bringing before the Institute. The invention, which is that of Mr. Alexander Dick, deals with the production of all kinds of metallic sections, from a simple round wire to complex designs which it would be impossible to roll, by forcing metal heated to plasticity through a die under hydraulic pressure. The principle is simple enough, being nothing more than that employed in the manufacture of bricks, drain-pipes, and similar articles. It is, however, the application of that principle to the purpose under notice that constitutes the ingenuity and originality of the invention, and which marks it as a substantial advance in metallurgical practice.

I do not forget that the principle of extrusion has been applied in the production of continuous lengths of leaden pipes and wire, and also of leaden rod for the manufacture of projectiles for small arms, and for other purposes. In those cases, however, the lead is pressed at a comparatively low temperature, whilst in the present instance the metal is operated upon at a very high temperature, namely, that of plasticity, or about $1000°\cdot F.$, and which varies considerably with different metals and alloys. It

was this necessary condition of high temperature that led to the
difficulties encountered by Mr. Dick in putting his invention in
practical shape, and which difficulties present features of interest
to steelmakers.

The process of manufacture consists in placing the heated
metal in a cylindrical chamber, at one end of which is a die.
Upon pressure being . applied at the opposite end the plastic
metal is forced through the die, issuing therefrom as rods
or bars of the required section and of a length governed by
the quantity of metal placed in the receiver.   This pressure-
chamber has not only to withstand the high temperature of the
contained metal, but has likewise, whilst under the influence of
that temperature, to meet the severe strain brought upon the
interior by the resistance of the metal to the pressure of the
hydraulic ram in forcing it out through the contracted area of
the die.   Hence the first and most important point to be
settled was the design of the cylinder and the material of which
it should be constructed.   Other difficult problems presented
themselves for solution as the work of construction progressed,
but they were of a less anxious and perplexing character than
that of the pressure-cylinder, which is the main feature of the
invention.

At starting several cylinders were made, some of cast and
some of wrought steel, in order to ascertain which material was
best suited for the purpose.   The chamber was 24 inches long
and 6 inches diameter internally, the walls varying in thickness
from 3 inches to 6 inches.   Surrounding the cylinder was an
annular chamber heated by a coke fire, the object of which was
to maintain the plasticity of the metal during the operation of
pressing.   In practice, however, it was found that the strains
set up by the unequal expansion and contraction of the walls of
the cylinder, added to the internal working pressure, soon deve-
loped cracks, thereby rendering the cylinder useless.

A series of experiments was therefore carried out by Mr. Dick,
with the object of finding a steel capable of standing the tem-
perature and pressure to which the container was subject in
working.   To this end he obtained cylinders of various steels
from several leading steelmakers, which he tested under working
conditions both of temperature and pressure.   In the result, how-

ever, he found that not one of the cylinders would stand more than 3 tons per square inch at the working temperature, Delta metal being the material operated with.   In all cases the cylinders bulged and developed longitudinal cracks, through which the metal was forced.   Thus for a time the progress of a promising invention was retarded, and the accomplishment of an important object rendered extremely doubtful.

Nothing daunted by failure, Mr. Dick set to work to devise other means whereby he hoped to accomplish his end.   In due course, and after the expenditure of a considerable amount of both time and money, he succeeded in producing the machine which I am about to describe, and which admirably fulfils its intended purpose.   The difficulty respecting the pressure-chamber, or container, was eventually overcome by dividing up the container into sections composed of concentric steel tubes alternating with annular spaces packed with a dense non-conducting material. This arrangement is based upon the principle that whilst steel, when heated to a high temperature, loses its integral strength, as proved by Mr. Dick's experiments, yet at lower temperatures it will retain its full power to resist pressure ; so that a cylindrical chamber formed of several comparatively thin walls, and protected from extreme heat, will resist pressure better than a chamber having a thick solid wall heated to a higher temperature.   A chamber surrounded by comparatively thin walls heated to a comparatively high temperature is not so injuriously affected by variations of temperature as a similarly heated chamber having a solid wall of greater substance.

By this compound system of construction, the liner, which is exposed to the extreme heat of the metal, may be made with a comparatively thin wall, and will not be liable to be fractured by unequal heating and cooling, and consequent expansion and contraction.   Further, in order that it may be capable of successfully resisting pressure, it is reinforced by means of the surrounding steel tubes, which, although of themselves thin, are insulated and supported by a dense packing of non-conducting material, and are therefore kept at a comparatively low temperature and in a condition to offer the greatest resistance, which condition is further mechanically influenced by a stout steel outer casing.

Another problem which took some time to solve was the selec-

tion of an efficient non-conducting material. The main conditions here were, that the particles of the material employed should be capable of being densely consolidated, should not injuriously affect either the liner or the outer cylinders, nor melt nor become decomposed at a high temperature. After experimenting with a variety of substances, Mr. Dick found that the best results were obtained from crushed granite mixed with a small proportion of borax. This compound satisfactorily fulfilled all the necessary conditions, and was therefore adopted as a non-conductor.

The apparatus as now constructed and in daily operation is illustrated in perspective in Plate IV. It is 16 feet in length, 6 feet wide, and 5 feet high over all. It consists mainly of the compressing cylinder or container and the hydraulic ram. A longitudinal section of the container is shown at fig. 1, and a transverse section at fig. 2. The container, which is 2 feet long and 2 feet diameter externally, has an inner liner of cast steel. The internal diameter of the liner varies in different containers from 5 inches to 8 inches, according as to whether it is wanted for pressing a small or a large charge, the container being changed as required. The liner is enclosed within a series of cylinders of ordinary mild steel spaced about $\frac{3}{4}$ inch apart, the annular spaces being filled in with the non-conducting material. The container is mounted on trunnions and fitted with worm-gearing for bringing it to a vertical position for being charged with metal and restoring it to the horizontal for the operation of pressing.

Great care has to be exercised in making the die-plates, the material of which is tungsten steel. They are formed with either one or several openings, each opening being of the section required to be given to the article to be produced. The edges of the openings in the dies are bevelled, so as to give free access to the metal under pressure, and to more perfectly condense it. The die-plate is mounted in a holder, in which it is easily fixed, or from which it is readily removed, as different sections are required to be pressed. As it is necessary to heat the die and its holder previously to each pressing operation, the die is fitted into a shouldered recess in the holder, which is coned to seat into a hollow metal block. This block is firmly held in position during
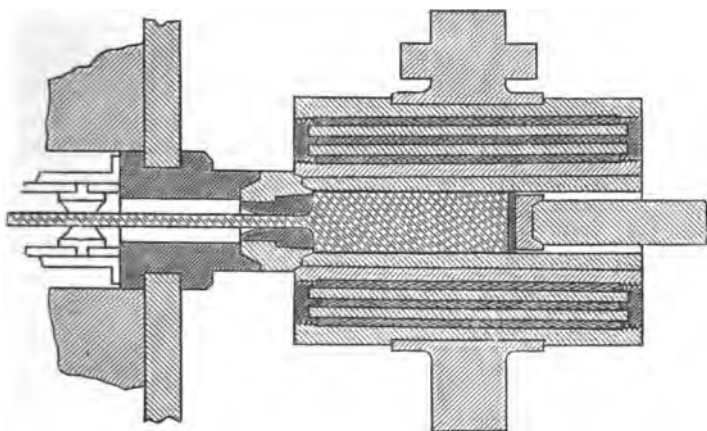
Fig. 1.
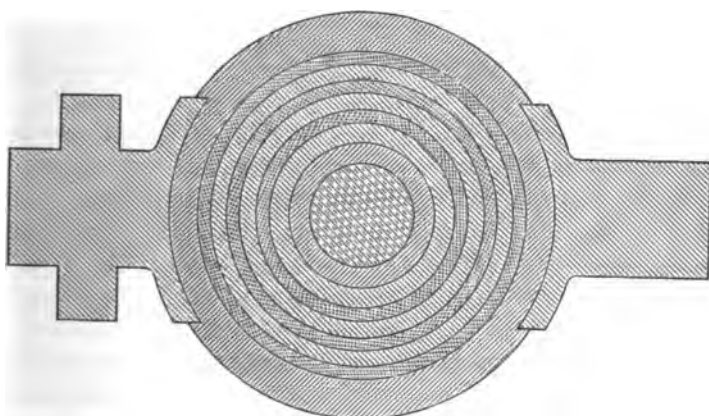
Fig. 2.
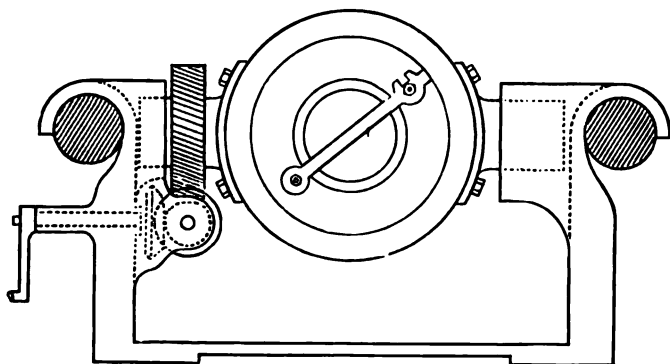
Fig. 3.

the operation of pressing by a pair of gripping-jaws actuated by hydraulic power.   The die-holder and the gripping-jaws are carried in a strong crosshead.   The die-holder and its adjuncts, together with a number of dies, as well as a container and some of the steel cylinders used in its construction, are seen in the perspective view of the machine.

The metal is forced out of the container and through the die by a hydraulic ram 18 inches in diameter, and working under a pressure of 2 tons per square inch.   The ram has a prolongation or extension, of reduced diameter, which forms the plunger of the container, entering it at the opposite end to the die.   A different plunger is used with each container, the diameter varying to suit the internal diameter of the container.   On starting to work each day, the container is first heated up by gas with a Bunsen burner, which quickly brings the liner to the temperature necessary to prevent the first charge of metal getting a chill. The container does not require reheating, as the liner remains red-hot after each run.

The working of this ingenious system of production will be best described from my own observations during a recent visit to the Delta Metal Works, Pomeroy Street, New Cross, London, where it has been in regular commercial operation for some time.   Upon that occasion the machine was running on an order for Delta metal rods 12 feet long by 1 inch diameter.   Of course, much greater lengths and much heavier sections are turned out as required.   The great variety of sections produced, some of very intricate character, is shown by the specimens on the table.   These specimens are samples of work ranging from light sections, such as wire weighing about $\frac{1}{100}$ of a pound per foot run, to heavy rounds, hexagons, and squares weighing 40 lbs. and over per foot run.   The die in use on the occasion of my inspection had four openings, thus producing four lengths, or an aggregate of 48 feet of rod at the same time.

A charge having just been put through, the opening at the front end of the container (that next the die) was closed by a removable plate or stopper, as shown at fig. 3, and the container was turned into a vertical position.   A charge of 1½ cwt. of molten metal was then poured from a ladle into the container, and was allowed to stand for about six minutes, so as to acquire

a plastic condition. The diameter of the plunger and that of a loose block which is placed between it and the charge (for a purpose which I will shortly explain) being less than the diameter of the steel liner, the plastic metal when under pressure would be forced backwards between the block and the liner were it not restrained. In order to prevent this back-flow taking place, a dished steel check-disc, which is less plastic and more rigid than the heated metal at the working temperature, is first placed on the top of the charge, and when the pressure is brought on, the disc is expanded and completely fills the bore of the liner, thus effectually preventing the back-flow of the metal.

Upon this check-disc was then placed the loose steel block just referred to, which, having been previously heated, prevents the cold end of the plunger chilling the charge of metal. The plunger being of smaller diameter than the liner, there is no fear of the latter becoming chilled by the former. To preclude the possibility of such an occurrence, the back of the loose block is recessed to receive a corresponding projection on the front end of the plunger, which is thus kept horizontal in its forward travel and prevented from coming in contact with the liner.

The loose block having been inserted, the container was brought into a horizontal position, the stop plate removed, and the container run up to the die-block, which, with the die, had been previously heated. The hydraulic pumps were then started, and in four minutes the charge was expelled and had become converted into four 1-inch rods, each measuring over 12 feet in length. The clips were then released and the ram continued its forward travel, pushing out the remaining metal, or stump, together with the die and its holder, as well as the check-disc and the loose block, leaving the container perfectly clear for a fresh charge. The rods were at once cut off from the stump or fag end of the charge to the exact length required and removed. The die and holder were then replaced by others, the container turned over into a vertical position, the stopper fixed in place, a fresh charge of metal teemed in, and as soon as it had become plastic the operation of pressing was again proceeded with. I may mention that the rate of travel

of the ram can be varied to suit the size of the charge or the special nature of the output.

With regard to the physical characteristics of the bars thus produced, it is obvious that, owing to the great pressure put upon the metal, its quality must necessarily be greatly improved, in the same way that Whitworth steel is improved by compression. In the first place, it is found to be perfectly homogeneous. The actual increase of strength in extruded bars over that of hot rolled bars of the same metal varies with the nature and composition of the metal or alloy. Taking ordinary yellow metal, the increase in tensile strength is 24 per cent., with a proportionate increase in elongation. Some tests made at Woolwich Arsenal with Delta metal bars produced by extrusion show a tensile strength of 48 tons per square inch, with 32·5 per cent. elongation on 2 inches, against 38 tons per square inch tensile strength and 20 per cent. elongation of rolled bars of the same metal. The samples exhibited have not been touched since they left the dies, and it will be seen that the surfaces are perfectly smooth, and that the various specimens require no further finish.

I have stated that at the time of my visit the mode of procedure was to charge the container with molten metal. The objection to this method of working is the delay occasioned at the press in waiting for the molten charge to set or become plastic, besides which there is the time occupied in various detail operations attending the charging of the container with molten metal. The result is that the average rate of working is only 25 charges per day of 10 hours. This method of working has since been improved upon by Mr. Dick, and the container is now charged with billets after they have been heated to the point of plasticity in the furnace seen on the left in Plate 1. With this method of working the output is doubled, easily reaching 50 charges and more per day. The labour cost per ton on the finished work is very small, being only the wages of two men and a boy per machine.

A larger press also is in course of construction which will have a 20-inch ram, and will be capable of turning out heavier work than any yet produced. Besides being in operation at the works already mentioned, the system is being worked under

license in the Midlands, and it has also been adopted in the Delta Metal Works at Düsseldorf.

It will thus be seen that we have, if not a new industry, at any rate a new industrial process, and one, moreover, which is of far-reaching importance. Having accomplished so much, it is not outside the bounds of possibility that, given an improved description of steel or other metal for the dies, other metals, such as iron and steel, which are less ductile and less expensive than those to which the system is at present applicable, may be used for the production of a still wider range of articles by extrusion. As a matter of fact, Mr. Dick is at the present time engaged upon experiments with the view of producing sections in iron and steel similar to those exhibited. Should he prove successful, I shall hope to have the ·pleasure of placing the results before the Institute.

DISCUSSION.

Mr. G. J. Snelus, Vice-President, said the paper was one of very considerable importance, because it opened up a new process for manufacturing sections from metal which had hitherto not been possible. He had had the opportunity quite recently of seeing a modified form of this extrusion of metals carried out on a very large scale.   He had taken a very considerable interest in it, because he believed there was a great future before it.   The case that he alluded to was the manufacture of a lead-covered cable by the British Insulated Wire Company, at Prescot.   By the kindness of a friend of his, who was the managing director there, he had paid several visits to that establishment, and last week he had the pleasure of seeing them covering a cable containing 150 pairs of telephone wires wrapped round with paper so as to form an insulating cover with an air space.   This cable was, he thought, over 3 inches in diameter, and they were pressing the fluid lead over it from an immense hydraulic press by a continuous operation in a most marvellous way.   The cable was being manufactured for our own postal authorities, and the company had had a very considerable amount of trouble in finding out the proper material to form the dies.   On the two previous occasions when he had been there, their immense press had been standing because they had had so much trouble with the dies ; but now they had overcome that, he was told, by the use of a particular kind of steel, and he had asked his friend to let him have a piece of that steel, so that he might have it analysed, and thus find out why it was so efficacious.

The author of the paper had pointed out the necessity of the dies being made of a particular material.   The dies in this case were made of tungsten steel.   It was rather curious that before he had seen the paper he had suggested to his friend whether tungsten steel would not answer the purpose.   They all knew that tungsten steel was a very hard material, and that it did not require tempering to produce its hardness.   There was no doubt that the process was limited so long as metal tubes were used as the containing vessels which was practicable for metals which

had a low melting point, but he thought it was quite within the bounds of possibility that eventually the extrusion of steel might be reached, and it was quite evident that the containing vessel could then no longer be metallic, and that they would have to then depend upon such materials as were used in the case described by the author for the lining between the metal tubes unless the pressure were great enough to deal with solid steel. He thought it was quite feasible that they might use earthy bodies for the lining. They knew that Whitworth used earthy material for lining the moulds in which he compressed fluid steel, and, therefore, some modification of Whitworth's lining might be used in this process.

He thought this process had a great future before it, and that it was not at all impossible that by-and-by it might be possible to deal with steel in this way. If so, it was quite evident that it would be a very important method of manufacture for a great variety of objects, principally, he would say, for tubes. They all knew the cost of making tubes at the present moment and the difficulty of making them, but if this process could be applied to tubes, there was no doubt that their cost of production would be very much cheapened. He thought that there was quite a possibility that this might be accomplished. They were indebted very much to Mr. Nursey for bringing this paper before them, and as one of the members of the Council who had to decide whether this paper was suitable for the Iron and Steel Institute, he was pleased to be able to say that he thought it might fairly come before the Institute, and he was quite sure that members would agree that they could not have excluded a paper of this kind, although at present it was only dealing with such metals as Delta metal, and had not yet dealt with the more important metal of steel.

Mr. G. A. DICK mentioned that a piece of steel bar had been made in this way accidentally. One of the steel check-plates remained inside the container, and was squirted out through the die; but the die completely collapsed, and that was the end of this steel experiment. If steel could be obtained sufficiently hard for standing the steel operation he did not think the container would give any trouble, because the metal was simply

pushed through the container, and the latter only had to resist the pressure. The container, he was persuaded, would be quite satisfactory, but a harder steel was required for the dies, and then steel bars could be made.

Mr. WRIGHTSON said the subject of the extrusion of metal was to him a most interesting one. It appeared reasonable to expect that what could be done in the case of lead could also be done with other metals, provided a material could be found for the container and dies that would stand the great heat and pressure to which they would be subjected.

On the motion of the CHAIRMAN, a cordial vote of thanks was accorded to Mr. Nursey, and the following paper was then read :—

PLATE IV.
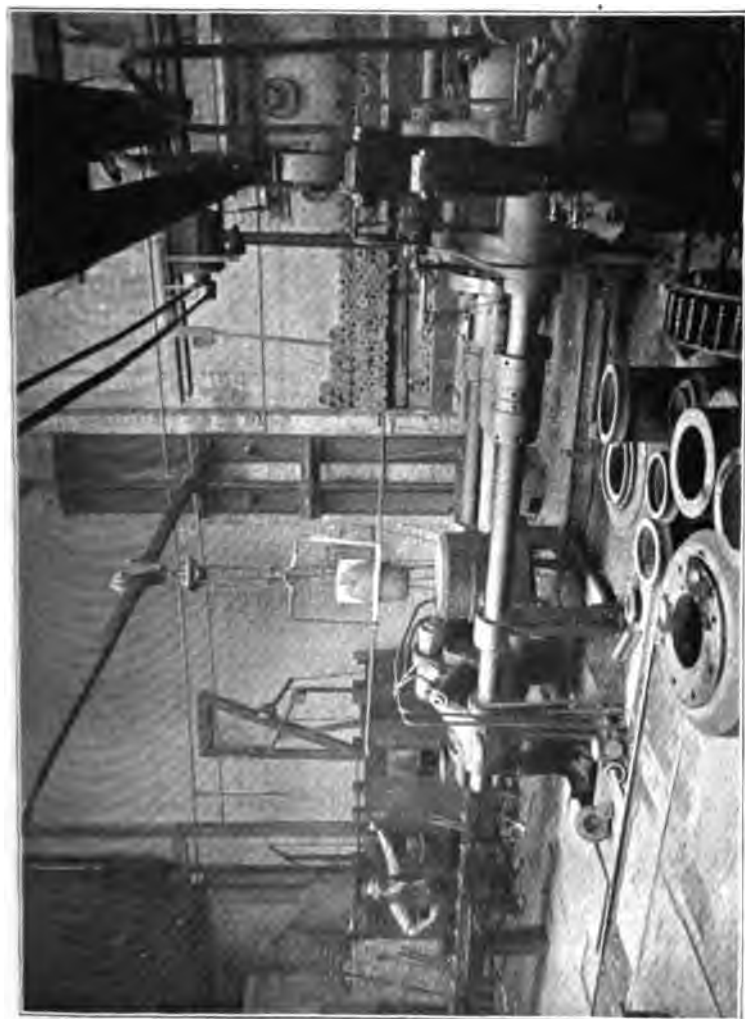
Production of Metallic Bars by Extrusion.
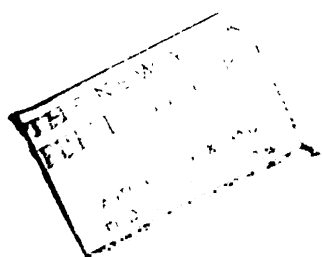
ON THE TREATMENT OF NEW ZEALAND
MAGNETIC IRON-SANDS.

By E. METCALF SMITH,

MEMBER OF THE HOUSE OF REPRESENTATIVES, NEW ZEALAND.

THE principal iron-sand deposit in New Zealand extends for about thirteen miles along the sea beach at New Plymouth, in the Province of Taranaki. The sea cliffs on this part of the coast consist of a combination of silica-sand and a rich magnetic iron-sand. The gradual crumbling of these cliffs, together with the large quantities of iron-sand brought down by the rivers and streams draining the slopes of Mount Egmont, result in a deposit of almost pure iron-sand on the beach, a large proportion of the lighter silica-sand being washed out to sea. Excavations have been made on the beach showing a depth of iron-sand of 14 feet, and the removal of any bulk of sand from the beach is replaced by the action of incoming tides. Iron-sand has been dredged up at a distance of three miles out to sea from this shore, proving that the deposit extends over a large area, and that the supply is practically inexhaustible.

This vast deposit of magnetic iron ore is in close proximity to extensive coal beds, limestone containing 88 per cent. of calcium carbonate, timber for charcoal, and every requirement for the manufacture of iron. The results of an analysis of Taranaki iron-sand given by Sir James Hector, the eminent geologist, are as follows:

Peroxide of iron } Protoxide of iron }	82·0
Oxide of titanium	8·0
Silica	8·0
Water and loss	2·0
	100·0

This, I believe, is the smallest proportion of titanium combined with the largest proportion of iron found in any iron-sand in the world.

By forming the iron-sand in combination with certain clays into a compound brick and smelting it in a blast furnace, using

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the fluxes I will now describe, I obtain a soft grey pig iron containing by analysis 1 per cent. of titanium. From this is produced bar iron containing 0·21 per cent. titanium.

The compound, of which the composition is stated below, is well pugged, pressed into bricks which are hard and compact and stand the pressure and grinding action in travelling through the furnace. The silica and alumina protect the fine particles of oxide of iron from being burnt, and allow the iron-sand to be treated as a rich compact iron ore.

Compound.

						Ton.	Cwt.	Parts of Titanium.
Pugged and pressed into bricks	160 parts iron-sand	.	.	.	.	1	12	12
	25 ,, blue clay	.	.	.	.	0	5	nil
	25 ,, yellow clay	.	.	.	.	0	5	nil

210 parts

Fluxes.

25 parts limestone	.	.	.	.	.	.	.	nil
25 ,, yellow clay	.	.	.	.	.	.	.	nil
25 ,, sugar loaf rock	.	.	.	.	.	.	.	nil
20 ,, lime and ashes residue from patent fuel						.		nil

305 parts   12 parts titanium

Reducing proportion of titanium to 3·6 per cent.

The yellow and blue clays used in the compound had the composition shown in the following analyses :—

Analysis of Tufa or Yellow Clay used in Compound.

Silica	.	.	.	.	.	.	.	.	.	41·000
Alumina	.	.	.	.	.	.	.	.	.	23·000
Manganese	.	.	.	.	.	.	.	.	.	traces
Oxide of iron	.	.	.	.	.	.	.	.	.	9·025
Lime	.	.	.	.	.	.	.	.	.	1·025
Water	.	.	.	.	.	.	.	.	.	24·014
Alkalies	.	.	.	.	.	.	.	.	.	2·000

100·064

Analysis of Blue Clay or Papa Rock.

Silica	.	.	.	.	.	.	.	.	.	54·21
Alumina	.	.	.	.	.	.	.	.	.	31·64
Iron protoxides	.	.	.	.	.	.	.	.	8·96
Manganese	.	.	.	.	.	.	.	.	.	traces
Lime	.	.	.	.	.	.	.	.	.	1·60
Magnesia	.	.	.	.	.	.	.	.	.	1·42
Water	.	.	.	.	.	.	.	.	.	2·17

100·00

In the year 1892 I smelted forty-five tons iron from Taranaki iron-sand in a small blast furnace, using the method above described with entire success, the iron running freely, the tuyeres being clean, and only 2 to 3 per cent. of iron oxides being left in the slag.

The following are results of the analyses of the pig iron and bar iron smelted by the process:—

	Pig Iron.	Bar Iron.
Iron	94·09	98·94
Manganese	traces	traces
Titanium	1·00	0·21
Silicon	2·12	...
Sulphur	0·02	traces
Carbon	2·33	0·46
Loss and substance not determined	0·44	0·39
	100·00	100·00

The pig iron is fairly granular, and a fragment flattens out when struck on the anvil. The bar iron is very fine grained and malleable, and is of excellent quality.

The following method of treating the fluid metal will, I think, commend itself. Having smelted the iron-sand, tap it into a ladle containing tarred iron-sand in the proportion of 4 cwt. to each ton of crude metal. The liquid metal will melt and absorb the iron-sand, and the tar will give sufficient carbon to retain the metallic iron in a fluid state. The metal so treated retains its greyness and fluidity, and if used for direct castings, there is a result of a gain in weight of 3 cwt. per ton, instead of a loss of 3 cwt. per ton, as is the case when remelting pig iron for castings.

In making wrought or bar iron, the tarred iron-sand compound can be added in the puddling furnace in the proportion of 50 per cent., and in making steel by the Siemens open-hearth furnace, 50 per cent. of tarred iron-sand compound may be used, yielding, together with what was placed in the ladle, a clear gain of 10 cwt. per ton.

The cost of manufacture of pig iron, superior in quality to the best Scotch, is £2, 7s. 3d. per ton, made up as follows:—

	£	s.	d.
Cost of fuel	1	4	0
Carriage, pugging, pressing, drying of compound iron-sand clays	0	10	3
Fluxes	0	4	0
Labour	0	8	0
Sundries	0	1	0
	2	7	3

By the special treatment described, bar iron equal in quality to the BBH can be produced for £7 per ton. The manufactured wrought iron, when reduced with charcoal, stood the extraordinary tensile stress of fifty-two tons to the square inch.

Mokau coal yields on analysis the following results:—

Fixed carbon .	54·0
Hydro-carbon	34·0
Water	10·0
Ash	2·0
	100·0

When passed through gas retorts, one ton Mokau coal, costing 13s. 4d. per ton at New Plymouth, will yield about 10,000 cubic feet of gas, which gas will do as much work in heating the puddling or steel furnace as 23 cwt. of raw bituminous coal costing 20s. a ton in New Zealand. By taking the carboniferous residue from the gas retorts and mixing it in the following proportions, I obtain the patent fuel employed.

10	cwt.	Mokau coal residue . .
6	,,	Raw bituminous slack coal
2	,,	Slag cement . . .
2½	,,	Coal tar . . . .
20½	,,	

Pugged and pressed into bricks. Costing about 12s. per ton.

This forms a fuel of a first-class character for smelting purposes, being almost pure carbon, hard and dense; it lasts a long time, produces a very high temperature, clear and bright, with little or no flame.

An analysis of this patent fuel by Mr. W. Skey, Government analyst, gave the following results:—

Fixed carbon	59·76
Volatile matter .	20·48
Water	0·72
Ash .	19·04
	100·00
Evaporative power . . . . 7·80	

The ash is obtained partly from the breeze and partly from the binding agent, the cement. After acting as a binding agent it is available as a flux.

There are various by-products obtainable from the slag in the form of bricks, slag cement, and slag blocks, all of which are of value in New Zealand.

The slag when ground is of value as a fertiliser. It consists, as shown by following analysis, chiefly of lime and silica :—

Lime .	40·0
Alumina	12·0
Silica .	42·0
Magnesia	2·0
Titanium	1·0
Iron oxides	2·0
Alkalies	1·0
Manganese	traces
	100·0

DISCUSSION.

Mr. BERNARD DAWSON asked if any particulars could be given as to the height and diameter of the blast-furnace which was successful in melting the iron - sand.   He remembered Mr. Chambers coming over with an introduction to various persons, among them being, he believed, Sir Lowthian Bell, and he was sent to him (Mr. Dawson) by some one he did not know.   He went to several small blast-furnaces of the country to get some one to lend one of their furnaces to try this sand.   As far as he remembered, about 200 tons of this black iron-sand was tried at various times, possibly by others besides Mr. Chambers ; 50 tons in one furnace, and 50 in each of three others.   As far as the furnaces were concerned the effects were simply disastrous.   The black sand came down into the fore part ; it was practically untouched.   Nothing could be done.   It could not be melted. He persuaded Mr. Chambers or his friends to incorporate some of this with tar and pitch, and get it melted in an open-hearth steel furnace in South Wales.   It was melted there, and, as far as he could remember, the analyses given by Mr. Smith were practically very much the same as these.   He should like to know the shape and the angle of the bosh, the height of the furnace, and some more particulars of any furnace that satis-factorily melted this iron-sand.   The author stated that in 1892 he smelted 45 tons of iron from iron-sand in a small blast-furnace.   Now was this charged into the blast-furnace as sand, or in the shape of briquettes ?

Mr. A. D. ELLIS said the author had stated that he had been able to make wrought iron that would stand 52 tons to the square inch, and the bar iron was said to be equal to B.B.H.   That was a very remarkable fact.   He should also be glad if the author could give the elongation and reduction of area of bars which had been tested and showed 52 tons tensile strength.   He had no wish to appear to doubt the results obtained by Mr. Smith, and only desired to .call the attention of the Institute to the extraordinary strain of 52 tons per square

inch, which was a strain that had hitherto been more or less confined to tool steel made in Sheffield, and had been altogether disassociated with a quality of iron such as B.B.H., and for this reason it was desirable to combine the results, showing the ductility of the metal as well as its tensile strain.

Mr. SMITH, in reply, stated that the elongation was 33½ per cent. The furnace was charged exactly as in England.

CORRESPONDENCE.

Mr. E. A. SMITH (Royal College of Science) was much interested in the paper by Mr. Metcalf Smith on the treatment of New Zealand magnetic iron-sands, as numerous attempts had been made to profitably smelt those valuable ores by making them into bricks by the admixture of various substances. More than twenty years ago works had been erected for the production of iron with the intention of using compound bricks made only of sand and clay with charcoal as fuel, but on account of the high cost of labour and other unfavourable local conditions the enterprise had proved a failure. After spending £17,350 in the erection of works, and putting the furnace in blast twice for three days on each occasion, the works had been closed and finally sold.

In a paper dealing with those magnetic iron-sands, recently read before the Institution of Mining and Metallurgy,* Lieutenant Walter Bassett Bassett remarked, that "at Hokitika in Westland large patches of the sand contained as much as 75 per cent. of magnetite, but inasmuch as this beach was fully exposed to the heavy surf thrown up by the prevailing westerly winds of the Southern Ocean, the character of the sand was found to change to a considerable extent with the weather, as after a heavy gale the upper layers of sand would be quite black and almost entirely composed of magnetite, while after light winds the colour was found to become somewhat lighter, thereby indicating the presence of a large percentage of silica."

* *Transactions of the Institution of Mining and Metallurgy*, vol. i. Part I. page 108.

From analyses, made at various times, of the Taranaki sand, however, it did not appear to vary in composition. The following somewhat more complete analysis of a sample of iron-sand obtained from the beach at New Plymouth, in the province of Taranaki, had been made in 1888 by the late Mr. Richard Smith of the Royal School of Mines, and was of interest for comparison :—

	Composition per cent.
Peroxide of iron	52·88
Protoxide of iron	29·60
Alumina	0·90
Protoxide of manganese	0·48
Magnesia	4·00
Silica	3·80
Titanic acid	8·14
Oxide of cobalt	trace
Phosphoric acid	none
Sulphur	none
	99·80

Metallic iron	60·03 per cent.

The large proportion of water present in the Mokau coal was characteristic of the class of coals termed " lignites," to which class it evidently belonged.

A sample of " coal " from the New Plymouth district was also examined by Mr. R. Smith. When the coal was heated in a covered vessel a bright, very slightly coherent residue was obtained, no true coke being formed. The gases given off during the experiment burnt with a yellow, luminous, somewhat smoky flame.

The percentage results obtained were as follows :—

Carbonaceous residue	48·50
Gases (hydrocarbons)	37·87
Water	13·63
	100·00

The amount of ash was not determined.

In connection with the analysis of slag given by the author it might be pointed out that the titanium present had been returned as titanium, and not as titanic acid, in which state it usually existed in slags.

The production of iron was not the only subject which had attracted the metallurgist in connection with the New Zealand iron-sand, as it had long been known that they contained gold.

The sands at Hokitika were said to be highly auriferous, and were worked for gold at the present time; the gold miners, with the crude methods at their disposal, earning in many cases as much as ten shillings per day. It would be of interest to know whether gold had been detected in the Taranaki sand, and if so, to what extent?

The CHAIRMAN, in the name of the Institute, expressed their gratification at Mr. Smith having come a distance of 16,000 miles to tell them what could be done in New Zealand. He was not, however, so sanguine as to think that ironworks in this country would be taken over there, at least not in his time. They were much obliged to Mr. Smith for a very interesting paper.

The following paper was then read:—

ON THE MAKING OF THE MIDDLE LIAS IRONSTONE
OF THE MIDLANDS.

By EDWIN A. WALFORD, F.G.S. (BANBURY).

THE "Marlstone" or Lias Ironstone of North Oxfordshire rests upon the marls of the Middle Lias.   For the most part it lies bare of its former covering of Upper Lias clays.   Its maximum thickness is about thirty feet.

The ordinary quarry face shows the upper half of the stone of the usual red-brown colour, the lower half with alternating bands of red and green stone.

The object of this paper is to determine :—

1. The character of the stone and its organic origin.
2. The making of the stone and its ferruginous changes.

In its calcareous condition as a green limestone its proportion of iron scarcely exceeds 17 per cent., and it is in that condition that it offers to us the best evidence of its origin.   Both in that condition, and also in its more weathered state, it can be seen to be made up of casts of recumbent cylindrical stems of coralliferous type.   These lie upon the plane of bedding, and their ends protruding from the weathered faces of the rock are easily distinguishable in the older quarries.   Their colour is lighter than the matrix.   The infilling is commonly calcite, crowded with organic remains, and with few ferruginous oolites.   A slab of the paving-stone, the top rag of the quarrymen, shows, in the flecking of its surface, sections and ends of the stems or tubular casts. In some cases they are detachable from the matrix.   I first noticed them, as a bed, at the point of junction of the Middle and Upper Lias, and have already called attention to them there, but not until late years has it become apparent that the main mass of the rock-bed is made up of these organisms.

Minor bands or beds of the rock are composed of the segments of sea-lilies (crinoids) or shells of mollusca.   In proportion to the ferruginising of the rock, so has proceeded the obliteration of the remains of its former organic life.

In order better to understand the "Marlstone" series two sections are given. I give also brief descriptions of their various beds, beginning at the bottom—the incoming of the calcareous conditions :—

MIDDLE LIAS MARLSTONE

ROAD STONE — 11' 0"

UPPER LIAS CLAY

PENTACRINITE BED
U.L. LIMESTONE
U.L. CLAY
U.L. LIMESTONE — 10' 0"

MARLSTONE MIDDLE LIAS

TOP RAC — 5' 0"

PENDLE — 2' 6"

BEST RAC — 4' 6"

MARLSTONE MIDDLE LIAS

MIDDLE LIAS MARLSTONE — -23' 0"

HORNTON. OXON

MARLSTONE MIDDLE LIAS — 30' 0"

MIDDLE LIAS MARLS
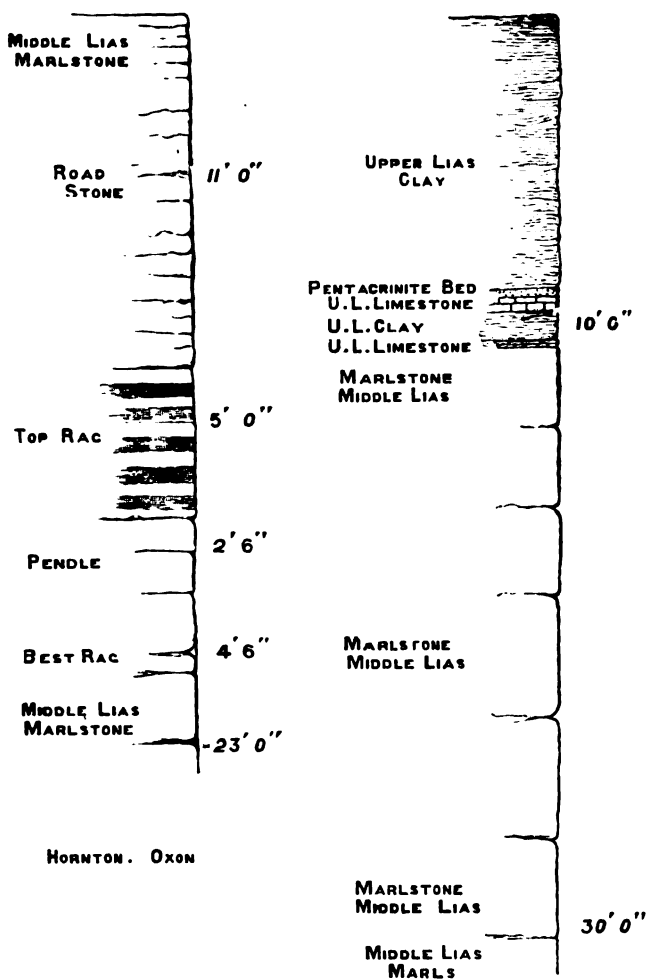
BLOXHAM RAILWAY CUTTING-GENERALIZED SECTION

BED 1. *The nodule bed.*—Red-brown impure ferruginous limestone. Black and brown shining nodules abundant ; mainly

derived from marls below or of organic origin. Remains of calcareous stem casts throughout. Oolites ferruginous, large, generally ovoid. Stone usually discarded as ironstone.

BED 2. *Best rag.*—Dark green limestone. Percentage of iron 9 to 15. Calcareous stem casts indistinct. Their contents distinguishable in micro-sections. Oolites small, frequently hollow, with concentric banding, enclosing granules of grey or green ferrous carbonate. The iron carbonate occurs also in a finely disseminated condition or irregular patches.

BED 3.—Brown impure ferruginous limestone, often with green cores.

BED 4. *Top rag.*—Hard thin-bedded ferruginous limestones with grey-green cores. Remains of calcareous stem casts abundant, lighter colour. Oolites small, solidified, filled with granular opaque calcite, or calcitic concentric lamella. Ferrous carbonate finely granular ; more frequently disposed around the oolites, or in patches.

BED 5. *Road-stone.*—Red-brown calcareous ironstone. Calcareous stem casts abundant; shown in less ferruginised places or cores. Oolites small; solidified. The calcitic interiors stained and charged with iron oxide or pitted with decomposed granules.

BED 6. *Transition bed.*—Limestone or marl, altered to an ochreous bed in places ; six inches or less in thickness. Oolites large, often separable from matrix. Some ferruginous oolites disposed like cobbles of a village pavement. Base clear calcite with scattered organisms. Terebratulae, ostracoda, &c., in transition state to oolites, and numerous hollow oolites. Like the incoming time of calcareous deposit (the nodule bed), the outgoing time was one of shallow turbulent seas with abundant molluscan life, and with coral growth.

In each of the mentioned beds microscopic examination shows how largely the remains of crinoida, bryozoa, ostracoda, spongidæ, and foraminifera entered into the composition of the rock as well as the calcareous stems and tube casts referred to.

In the railway section at Bloxham, near Banbury, the Upper Lias beds with some Marlstone have been brought down on each side of a narrow strip of Marlstone less than fifty yards broad. The stone on either side, protected by the clay covering, is

mainly green, and shows the calcareous stems abundantly, whilst the uncovered rock is ferruginised and the organic remains for the most part washed out.

With the slow compacting of the blue and green muds of the " Marlstone " time came the replacement by calcite of the sculptured calcareous tests of the microzoa and the skeletons of bryozoa, and at a later stage still followed the infilling of their chambers with the grey granules of ferrous carbonate. How solid were the cylindrical coralliferous stems, which made up so much of the rock, can be inferred by the slowness of their decomposition and the rarity of the occurrence of ferruginous oolites *within*, though they may occur freely *around* the stems.

The best rag is a porous rock, soft enough to be cut with a hand-saw. A clay seam frequently separates it from the nodule bed below. The top rag, on the contrary, like the road-stone above, is compact and dry. The process of solidification has been carried on in these upper layers to a greater degree. In the top rag especially is this solidification noticeable in the compactness of the oolites. In the road-stone the oolites appear to have decayed again after solidification—probably with the ferruginising of the beds. The see-saw of wet and dry seasons through the long ages has been an important agent in the alteration of the rock from the green state we see it under when well clay-covered, to its red-bröwn stage when uncovered and as an ironstone. Calcareous deposit first, prior to the removal of the clays by denudation, ferruginous change later, with corresponding destruction of the calcareous rock in proportion as it became charged with iron. We know that enormous masses of sedimentary rock formerly spread above the present surface, clays, limestones, ferruginous sands, ferruginous limestones, and that each in turn was slowly destroyed by atmospheric agencies. And as the thousands of feet of Jurassic, and perhaps of Cretaceous, deposits were dissolved, each in turn contributed its store to the solidification or alteration of the rock below. The laminated banding of the oolites is evidence of the abstraction of lime from the water, which it has taken from the beds above to give up again with the alternations of condensation produced by the dryings of the saturated rock.

In the altered state of the microzoa, and also of the larger organisms, is shown change after change of structure, until the fossil remains as it were a shadow of a former being.   Under these conditions it is difficult to read aright the tangled story of a past time.   Fortunately an occasional incoming of argillaceous deposit has packed away, in cores and pockets, fragments of the old life, often with the perfectness of a to-day's shore.

DISCUSSION.

Mr. G. J. SNELUS, Vice-President, said it happened that the question of the formation of these particular ores which generally went by the name of Northamptonshire ores was a favourite subject of his when he was chemist at the Dowlais Works. It was then his daily duty to go over the samples of ores, and take specimens for analysis. They were then using 7000 or 8000 tons of Northampton ore per week, and he had a great deal of contact with it. He was struck with the fact which the author of the paper had brought forward, that they began originally by organic deposits. It was evident, to his mind, however, that a large portion of the Northamptonshire deposits were due to secondary action. If they examined Northamptonshire ore they would find that there were large pieces of the ore in the form of dog-tooth spar; and that the centre consisted very largely of carbonate of lime, which was followed by the green oxide of iron, and that ultimately this green oxide was peroxidised to the brown oxide. The changes could constantly be traced. Therefore, in addition to the action which had been described of the filling-in of these coralline formations by the iron solution, there had apparently been a secondary action of the crystallisation of the carboniferous material into the form of dog-tooth spar, then that had been replaced in some manner through the percolations of iron solutions by protoxide of iron, and ultimately that protoxide had been converted again into the peroxide. An investigation of this kind was exceedingly important, and it was always well to know as far as possible how nature had yielded the bountiful products exhibited in the various forms of iron in use.

On the motion of the CHAIRMAN, a vote of thanks was accorded to the author, and the meeting was adjourned until Friday, 8th May.

On reassembling, the following paper was read :—

THE INTRODUCTION OF STANDARD METHODS OF ANALYSIS.

BY THE BARON HANNS JÜPTNER VON JONSTORFF
(NEUBERG, AUSTRIA).

IN compliance with an invitation from the Council of the Iron and Steel Institute, I have pleasure in presenting the following account of the introduction of standard methods in the analysis of iron and steel.

In the first place, I must point out that the phrase "introduction of standard methods of analysis" is, strictly speaking, a catch word, and that it would perhaps have been better to speak of a unification of analytical results.   Adopting the most general standpoint, it may be said that the only important point to be attained is to ensure that analyses of one and the same sample made by different individuals shall agree well together, and give as accurate results as possible ; and further, that it can be considered somewhat a matter of indifference whether this object is attained by the use of similar methods or in any other possible way.   Indeed, it will be seen subsequently, that considerable objections may be raised against the introduction of standard methods for general use.

That this object is not at the present time attained in many cases, is generally known.   Nevertheless, I shall venture to cite some examples of analytical differences which may not be without interest, inasmuch as the analyses in question were made, not by beginners, but by experienced, and even eminent, analysts.

A chill-roll * was examined in two laboratories (A and B), and as quite incredible differences were obtained, a check analysis (C) was made.   The results were as follows :—

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* Jüptner, *Fortschritte im Eisenhüttenlaboratorium*, 1895, vol. i. p. 3.

	A.	B.	C.
	Per Cent.	Per Cent.	Per Cent.
Carbon	3·50	2·785	2·767
Silicon .·	1·30	0·668	0·677
Manganese	2·40	trace	0·050

In one and the same steel sample two laboratories found :—

	A.	B.
	Per Cent.	Per Cent.
Phosphorus	0·11	0·0870
Arsenic	no trace	0·0387
Total	0·11	0·1257

In one and the same laboratory there was found in the same sample of pig iron which was sent for analysis twice under different designations :—

	Per Cent.	Per Cent.
Combined carbon	0·91	0·617
Graphite	2·67	3·033
Total carbon	3·58	3·650
Silicon	2·65	1·179
Manganese	0·088	0·105
Phosphorus	0·355	0·394

Happily, however, such enormous differences are rarely met with ; but the fact that they can occur at all is undoubtedly a matter for reflection, and renders it a pressing duty to devise a method of obviating such occurrences.

Notwithstanding most careful and frequent repetitions of the analyses, differences are still met with, which under some circumstances may be considerable. Thus the investigation of four standard samples by the English, Swedish, and American Committees gave, according to J. W. Langley,[*] the following results :—

* *Journal of the American Chemical Society*, 1893, p. 448.

Standard.	Constituents.	English Commission.	Swedish Commission.	American Commission.	Maximum Difference.
I.	Carbon	1·414	1·450	1·440	0·036
	Silicon	0·263	0·257	0·270	0·013
	Sulphur . . .	0·006	0·008	0·004	0·004
	Phosphorus . . .	0·018	0·022	0·016	0·006
	Manganese . . .	0·259	0·282	0·254	0·028
II.	Carbon	0·816	0·840	0·807	0·033
	Silicon	0·191	0·185	0·207	0·017
	Sulphur . . .	0·007	0·004	0·004	0·003
	Phosphorus . . .	0·014	0·015	0·010	0·005
	Manganese . . .	0·141	0·145	0·124	0·021
III.	Carbon	0·476	0·500	0·452	0·048
	Silicon	0·141	0·150	0·152	0·011
	Sulphur . . .	0·008	0·006	0·004	0·004
	Phosphorus . . .	0·021	0·021	0·015	0·006
	Manganese . . .	0·145	0·170	0·140	0·030
IV.	Carbon	0·151	0·170	0·160	0·019
	Silicon	0·008	0·015	0·015	0·007
	Sulphur . . .	0·039	0·048	0·038	0·010
	Phosphorus . . .	0·078	0·102	0·088	0·024
	Manganese . . .	0·130	0·130	0·098	0·032

The examination of the four samples by the chemists of the British Committee gave the following results :—

Standard.	Constituents.	W. Jenkins.	G. S. Packer.	J. Pattinson.	E. Riley.	J. E. Stead.	Maximum Difference.
I.	Carbon . .	1·43	1·44	1·393	1·387	1·419	0·053
	Silicon . .	0·260	0·28	0·271	0·250	0·252	0·030
	Sulphur . .	0·010	traces	trace	0·004	0·007	0·010
	Phosphorus .	0·02	0·017	0·019	0·017	0·016	0·004
	Manganese .	0·26	0·267	0·263	0·278	0·229	0·049
II.	Carbon . .	0·82	0·85	0·802	0·811	0·796	0·054
	Silicon . .	0·200	0·197	0·182	0·192	0·186	0·018
	Sulphur . .	0·008	traces	0·007	0·007	0·007	0·008
	Phosphorus .	0·02	0·012	0·012	0·012	0·012	0·008
	Manganese .	0·14	0·144	0·145	0·140	0·137	0·008
III.	Carbon . .	0·55	0·46	0·461	0·456	0·455	0·095
	Silicon . .	0·144	0·14	0·140	0·153	0·130	0·023
	Sulphur . .	0·015	traces	trace	traces	0·008	0·015
	Phosphorus .	0·02	0·022	0·022	0·016	0·024	0·008
	Manganese .	0·13	0·130	0·158	0·144	0·161	0·031
IV.	Carbon . .	0·165	0·146	0·142	0·147	0·154	0·013
	Silicon . .	0·008	0·008	0·009	0·008	0·009	0·001
	Sulphur . .	0·040	0·036	0·040	0·041	0·040	0·005
	Phosphorus .	0·08	0·08	0·075	0·081	0·075	0·006
	Manganese .	0·13	0·130	0·130	0·124	0·137	0·013

The examination of the fifth standard sample by the English Commission yielded :—

Constituents.	G. S. Packer.	J. Pattinson.	E. Riley.	J. E. Stead.	Maximum Difference.
Combined carbon	0·055*	0·034	0·036	0·035	0·021
Silicon . .	0·006	0·005	trace	0·008	0·008
Sulphur . .	0·030	0·030	0·023	0·036	0·013
Phosphorus . .	0·040	0·041	0·041	0·042	0·002
Manganese . .	0·275	0·310	0·258	0·317	0·059
Copper . .	—	—	0·025	—	—

The American Commission published† the following results of phosphorus determinations in a series of steel samples :—

Analyst.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	Remarks.
W. P. Barba . .	0·041	0·015	0·095	0·091	0·041	Sample No. 3 contained an appreciable quantity of arsenic.
A. A. Blair . .	0·040	0·016	0·098	0·091	0.041	
T. M. Drown . .	0·042	0·016	0·104	0·090	0·042	
C. B. Dudley . .	0·040	0·016	0·099	0·097	0·039	
P. W. Shimer . .	0·041	0·017	0·098	0·096	0·039	
Maximum difference	0·002	0·002	0·009	0·007	0·003	

The differences in these analyses are, it is true, incomparably smaller than in the examples previously cited, and for many technical purposes may be disregarded. They are still, however, quite appreciable enough to have a disturbing influence, not only in purely scientific researches, but also in many instances in practice. The analyses are, however, it must not be forgotten, the careful work of special commissions, and not the average results of very busy works laboratories, from which equally careful analyses cannot well, as a rule, be expected, on account of the excess of work, almost all of which has to be disposed of in the shortest possible time.

In saying this, I have no intention of decrying the value of ironworks laboratories. On the contrary, I desire to direct

* The high percentage of carbon reported by Packer is held to be due to the fact that the determination was effected in T. Brown & Co.'s laboratory in Sheffield, in the centre, that is, of a large works, and therefore in an atmosphere in which dust was always present, so that with the greatest care it was not possible to obtain concordant results. This fact indicates the great importance of maintaining a condition that is subsequently dealt with (favourable position of the laboratory).

† *Proceedings of the American Society of Civil Engineers,* vol. xxi. pp. 59–67.

your attention to this point in order to show you that it is just these laboratories, which at the present time, under the pressure of urgent necessity, have to conduct enormous numbers of analyses, and, besides this, have frequently to leave to others much more of the laboratory work than the chemists engaged there like—it is just these laboratories that do more work, and better work, than can reasonably be expected from them under these conditions.

Even small analytical differences, however, which unfortunately can in no way be regarded as rarities, frequently make themselves felt in an objectionable manner, not only in purely scientific researches, but also in many cases in practice.

Thus, for example, if a given composition or a given limit to the percentages of the various constituents is specified by the purchasers as a condition of acceptance, it is evident that even very small deviations in the analytical results may have disagreeable consequences. An instance that came under my notice will illustrate this. In an engineering works an order was given for boilers, the plates of which were specified not to contain more than 0·020 per cent. of sulphur. The plates were supplied by an ironworks, and in them 0·014 per cent. of sulphur was found by the producer. As the limit of the contract was very short, the engineering works found it necessary to work the plates supplied on the strength of this determination, without waiting for the check-analysis required by the purchaser. The boilers were finished when the second analysis came to hand; but this yielded 0·034 per cent. of sulphur !

Such examples, of which many might be cited, clearly show the urgent necessity of doing something to meet this evil, and the great importance of being able to be perfectly certain of the results yielded by chemical analysis. The result will show, and reference to it may not be out of place here, that more advantages will also accrue than would at first sight be imagined. If, for example, it were made absolutely certain that the limits of error of the determination of sulphur amounted to say ±0·005 per cent., it is evident the works in question, in order to satisfy with safety the required conditions, could supply only such plates as were found to contain not more

than 0·010 per cent. of sulphur. As, however, it is only rarely that an ironworks is in a position to regularly produce a material with so low a percentage of sulphur, the immediate consequence would be that the purchaser would be compelled to raise proportionately the limits fixed for the allowable percentage of sulphur. In what manner the investigations required for the solution of this problem can be, and will be, of still further practical use in this direction will be shown later.

The necessity of doing something in order to obtain standard, that is, concordant, analytical results has long been recognised, and in consequence endeavours in this direction have been made for many years past.

Thus, at the instigation of Dr. Dudley, in Altoona, Pennsylvania, an American Commission was formed, consisting of Messrs. Metcalf, Rodd, and Hunt of Pittsburgh, Barba and Blair of Philadelphia, Drown of Boston, and Shimer of Easton, with Mr. John W. Langley as President. This Commission, since the Chicago World's Fair, has worked in conjunction with the English Commission, consisting of Professor W. C. Roberts-Austen (President), Sir F. A. Abel, Bart., E. Riley, J. Spiller, G. J. Snelus, W. A. Tilden, and Thomas Turner, and with a Swedish Commission, consisting of Dr. A. Tamm, Professor C. G. Särnström, Dr. P. E. W. Öberg, Professor O. Pettersson, and R. Åkerman as President. Reports of the British Committee were published by the British Association in 1889, 1890, 1891, 1892, and 1893. Again, in Germany, chiefly by the initiative of the *Verein deutscher Eisenhüttenleute*, and of the late Dr. von Reis, a Commission was formed with similar objects, consisting of Messrs. Wolf of Dortmund, Glebsattel of Oberhausen, Corleis, Gerstner, and Salomon of Essen, and Becker of Rothe Erde, near Aix-la-Chapelle. Moreover, a number of eminent chemists have also for some years past been engaged on similar work, and their endeavours have been supported by premiums offered by technical societies.

In technical literature these endeavours are very noticeable. Thus in the more recent works on iron analysis (Blair, Wedding, &c.), there is a growing attempt to present comparative criticisms of the various methods, and to study more exhaustively their sources of error.

I myself have been occupied with this work for many years

past, and shall here merely refer to an article published in the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen* in 1884 on the accuracy of chemical analysis, and to my two larger treatises, *Praktisches Handbuch für Eisenhütten-Chemiker*, 1885, and *Fortschritte im Eisenhütten-Laboratorium in den letzten* 10 *Jahren*, 1895-96, in which not only are the causes of errors in analysis discussed generally, but special attention is also given to criticising the various methods.

At the fifth International Congress for the Unification of Methods of Testing, held at Zürich in September 1895, the proposal was made by Dr. Wedding and myself, based on papers on the subject read by us, that support be afforded to an International Commission to deal with the solution of this problem, and the motion was carried by the Conference.

Turning now to the problem itself, it is evident that its solution must be preceded by an accurate knowledge of the causes that bring about differences in analyses, so that it is first necessary to consider the sources of error in chemical analyses.

Regarded from a general point of view, these are—

1. Gross errors in the analysis.
2. Impure reagents.
3. Errors due to the apparatus, &c.
4. Errors due to the operations.
5. Errors due to the analytical methods.
6. Personal errors.
7. Errors due to differences in the calculation of the analyses caused by the values of the atomic weights on which they are based.
8. Want of homogeneity of the sample.

I trust that it will not be out of place to consider a little more closely these various sources of error.

1. Gross errors in the analysis, with which may also be classed confusion of samples, errors in calculation, &c., should obviously never occur.   Their occurrence is due to ignorance, want of skill, or carelessness on the part of the analyst, to defective equipment of the laboratory, and to overwork.

What can and must be done to obviate these errors is evident:

Employment of skilled analysts, diminution as far as possible of laboratory work, suitable equipment of the laboratory, and avoidance of overwork. At the same time, it may not be out of place also to consider these points more closely, for now and again it is just in this direction that grave errors are committed. The analysis of steel is generally recognised to belong to the most difficult and most ticklish portion of chemical analysis, and should only be entrusted to skilled and reliable analysts. Moreover, it is, too, by no means the only duty of the ironworks' chemist to conduct his analysis according to known recipes, as in a cookery-book. Not only has he frequently to solve problems in which the known methods leave him in the lurch; but it is also under all circumstances his task, his duty indeed, to make as thorough a study as possible of new methods described in the literature of the subject. In this way his knowledge is widened, and the possibility is presented of introducing effective new methods, and of making it clear to himself what differences can arise by the employment of other methods than those he employs. He, however, has also an opportunity of so modifying new methods that they can be applied with distinct advantages to practical use. Any one who is unable to test an analytical method thoroughly is unfit to be chemist in an ironworks laboratory.

Analytical chemistry, and not least the branches of it dealing with the investigation of iron and steel, has become so extensive and so progressive a science, that any frequent change of staff in ironworks laboratories is as far as possible to be avoided. For this reason the principle occasionally adopted of employing beginners in the metallurgy of iron in the laboratory, and after a time to find places for them in the works themselves, is to be condemned. It is certainly true that it is of considerable use to works officials if they have worked for some time in the works laboratory; but it must not be forgotten that the works laboratory is provided in the first place to conduct accurate analyses, and if it is also provided in the interest of the works, it is obviously an absolute necessity that the interests of the laboratory should be fully and completely preserved.

That in modern works laboratories a part of the work must be left to unqualified assistants is a matter for regret, which must be ascribed to the fact that an enormous number of analyses

have to be got through as rapidly as possible.   It is indeed true
that there are such assistants who possess all the qualities for
enabling them to carry out analytical work, if a skilled chemist
is at hand on the one hand to check their work, and on the other
to come to their aid in the case of need.   Such assistants are,
however, very rare, and on the other hand I have seen, in small
works laboratories, where unqualified assistants work without
supervision, things (such as determining silicon in grey pig iron
weighing the silica *with the graphite,* in determining tungsten in
tungsten steel by fusing the silica and tungstic acid with potas-
sium bi-sulphate, and extracting the fused mass with boiling
water, &c.) which render it my duty to advocate most urgently
the limiting, as far as possible, the employment of such assistants
as these.   Moreover, it is a well known fact that the best and
most certain methods, when they are currently used by these
assistants, do not yield nearly such accurate results as in the
hands of qualified chemists, and that the supervising chemist has
constantly to guard against the introduction by the assistant
in the course of time of slight carelessness in performing his
duties.

It is obvious that the size and equipment of the laboratory
must fulfil the given requirements.   I can therefore confine
myself to a few points which now and again are not sufficiently
regarded.

The laboratory must be of sufficient size to utilise satisfactorily
the working efficiency of those engaged in it, and to avoid con-
fusion.   The balance must be in a separate place.   The situation
of the laboratory should be so chosen that it suffers as little as
possible from dust and vibration.   It should therefore be placed
neither immediately next to the street, nor too close to the
works.   It is decidedly open to objection to have a laboratory in
a works, and the slight advantage thereby presented of con-
venient access from one to the other is not nearly enough to
compensate for the drawback that in such a laboratory accurate
results can never be obtained with certainty.*

For hygienic reasons the height of the laboratory should not be
less than thirteen feet, and perfect ventilation is requisite. Central
heating of the laboratory is very desirable, more especially because

* See above, the remark in connection with Packer's carbon determination.

the dust caused in the lighting and emptying of the stove is avoided. Gas is almost indispensable, and can, where coal-gas is unavailable, be easily supplied by a small oil-gas plant. I may also mention that the amount of work done in a laboratory is increased if there is no break in the middle of the day, the work being carried on continuously, and finished at a correspondingly earlier period. In this way opportunity is afforded the staff of obtaining free time for the relaxation so necessary after arduous laboratory work.

It is hardly necessary to state that overwhelming the laboratory with work should be avoided if trustworthy work is anticipated. A laboratory working like a factory is preposterous. And yet in this respect many are to blame. How is it possible to avoid errors and faults with excess of work in many cases almost inconceivable ?

The demands here set forth in the interest of the laboratories (but also in that of the iron industry) will perhaps appear to many as exaggerated. If, however, it is desired to obtain really good and trustworthy analyses, they are not overstated at all. On the contrary, they are the indispensable preliminary conditions which, if unfulfilled, result in all subsequent work having but little value. Nevertheless, it can and will be replied that in all cases such painful accuracy is not required, and how can small works soar to the heights of the required installations ?

Here, however, it is merely a question of alternatives.

In many cases the greatest possible accuracy is indispensable, and without it there is no certain agreement between the investigations of different laboratories. Where, however, it is desirable to have accuracy and agreement with other analysts (and this is very frequently the case), the technical laboratory of an iron-works is a scientific establishment, and must be suitably provided as regards staff, space, time, and equipment.

Undoubtedly there are many investigations (especially the daily analyses for checking the working) in which such minute accuracy is not absolutely necessary, and for such purposes the demands may be considerably modified. If this is done, it must be clearly understood that it is no longer a question of a *chemical laboratory* but of an *assay office*, and that the determinations thus obtained are not, as a rule, comparable with the results of actual

chemical analyses. Where, too, chemical laboratories and assay offices are under the same direction, it is advisable to place them in distinct buildings, and not to employ the staff simultaneously in the two.

In this way it is possible to meet the requirements cited above. Any works, even the smallest, can have its assay office, if one of the managers will only give himself the trouble of superintending the work in it. Larger works, however, can, and should, have their own actual chemical laboratory, provided with a suitable staff and equipment. The comparatively small expense will certainly be well repaid. But small works, which are not in a position to provide and to maintain their own well equipped laboratory, do best to have recourse to a neighbouring private laboratory of repute. In that way they fare better and cheaper than with a badly equipped laboratory of their own, which costs, it is true, very little, but which, from the inaccuracy of the work done, does more harm than good.

2. *The want of purity of the chemical reagents* is, as Dr. H. Wedding rightly remarked in his paper at the Zürich Congress, "most easily corrected by care on the part of the chemist *before* using the reagents. By paying careful attention to this point, very advantageous pressure will incidentally be brought to bear on those manufactories which produce reagents on a large scale." Nevertheless, testing the purity of the reagents is not always so simple as many imagine, and this, C. B. Dudley,* for example, has clearly proved when he says that, as a rule, blank trials are better than the purity tests, as an investigation of the reagents is often accompanied by most difficult manipulations, and it does not of itself clearly show how the impurities will affect the analysis.

3. *Errors due to the apparatus* include all errors in weighing and measuring, errors which are caused by neglecting to reduce weights and volumes to vacuum or to normal pressure and temperature, &c. Although these errors are more or less recognised, and are in many cases so small that they may be neglected, I venture at least to refer to them briefly, as every analyst has to assure himself as to their magnitude in order to be able to allow for them in cases where it appears to be necessary.

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* *Journal of Analytical and Applied Chemistry*, 1893, p. 5.

a. Errors in Weighing.—It is obvious that the balance employed should not be too sensitive nor too sluggish, and that the sensitiveness of the balance (a very important point in steel analysis) should be as nearly as possible constant with loads of various weights. On the other hand, the most perfect equality of the arms of the balance is not absolutely necessary, as both the substances to be weighed and the weights are always placed on the same side of the balance, and *absolute* accuracy of the weighing is in no way desired, as even in important determinations of percentage composition relative accuracy of the weighings perfectly suffices. This circumstance necessitates, however, that, at any rate, in all cases in which considerable accuracy is required, all the weighings for *one* analysis must be performed on the same balance.

It is important that the terminal knife edges of the beam should be parallel to each other and to the central knife edge, as otherwise an accurate weighing is quite impossible. Thus, for example, with a balance made by an eminent firm, in which this condition was not fulfilled, two weighings of a small platinum crucible immediately following one another gave a difference of 0·007 gramme.*

Accuracy of the weights is similarly urgently required for obtaining correct weighings, but in this case, for the reasons previously given, relative accuracy suffices. In order to effect this, a comparison of the separate weights is indispensable. Further, a testing of the graduation of the beam is not to be neglected.

In the course of time the weights, however, suffer changes, which, according to a report of the German Commission,† may be ascribed mainly to the following causes:—

1. *Wear.*—As a rule, the wear is less in proportion to the smoothness of the surface, and therefore highly polished weights are to be preferred to those with a dull surface.

2. Accumulation of foreign matter on the surface of the weights.

3. *Internal Oxidation.*—This takes place within the blowholes in the castings, and is considerably assisted by the penetration

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* Jüptner, *Praktisches Handbuch für Eisenhütten-Chemiker*, p. 83.
† *Chemiker Zeitung*, vol. x. p. 1481.

of salt solutions in the galvanic gilding or nickel-plating. The weights, therefore, after the receiving of a galvanic deposit, should be repeatedly boiled in water, in order to remove the penetrated salt solution. Old weights that have become inaccurate by internal oxidation should, after readjustment, not be again gilded. Very small weights may advantageously be made, not of cast brass, but of pieces of copper, which have been obtained from a piece of electro-deposited copper, or from metal rendered compact by rolling and hammering.

The balance also suffers similar changes to the weights. Besides these permanent changes, however, there are temporary changes, which may briefly be discussed.

The length of the balance-beam may be changed unequally by heating. The weighing of warm substances should therefore be avoided, and care should be taken to avoid any one-sided heating of the balance, whether it be from a gas or petroleum lamp placed nearer to one beam than to the other, or whether it be merely from sunlight reflected from a window-pane. For this reason, as well as a protection from disturbing currents of air caused by breathing, weighings should be conducted only with closed balances. The balances made by A. Ruepprecht, Vienna, in which all the weights under one gramme can be placed in position with the case closed, are for these reasons deserving of much commendation.

According to R. Hennig,* air currents may also be induced when liquids are weighed in wide vessels owing to their evaporation, which may result in an alteration of the point at which the balance comes to rest. An error in weighing, which amounted to 0·4 milligramme, resulted in one such instance, and this could only be eliminated by determining the zero point of the balance immediately after the weighing, and without removing the liquid from the balance case. The presence of a substance which will absorb the vapour increases the error, such as calcium chloride or sulphuric acid in the case of moisture. The zero point of the balance may, too, be changed by an electrification of the balance supports, after rubbing one side with a cloth, or by frequent lightly applied friction, such as moving backwards and forwards a box of weights on the cover of the balance case. Similar errors

* *Zeitschrift für Instrumentenkunde*, vol. v. p. 16.

may also be induced, according to the observation of the German Commission,* in removing glass or quartz weights from the box by their rubbing against the cloth lining, and so becoming electrically charged.

The condensation of moisture, or even it may be the accumulation of a denser gas layer on the surface of dry non-hygroscopic bodies, induces further errors in weighing, especially in the weighing of U-tubes, &c.   Thus G. Papasogli † found that various powdered substances, which had been dried over sulphuric acid, increased in weight during the period of weighing (from three to six minutes) by from 0·001 to 0·003 gramme.

When closed vessels are to be weighed, care must also be taken that the air enclosed in them has the same temperature and pressure as the surrounding atmosphere.

It has further been shown by T. E. Thorpe ‡ that the zero point of the balance is subject daily to slight variations, just as if one arm of the balance expanded somewhat more during the course of the day than the other.

β. *Errors in Measuring.*—It is of course evident that the various measuring vessels must be examined as to the correctness of their division and their relative agreement with each other. As a rule, an error of 0·1 per cent. of the volume to be measured may in such cases be tolerated, although in especially important cases it will be necessary to take into calculation the exact volumes, for which reason it is advisable to provide correction tables for the measuring vessels that are used.

In reading off the volumes, errors may also be made—errors in reading off—which may in part be parallax errors, and in part be due to errors made in estimating portions of the divisions into which the measuring vessel is subdivided.   Various methods have been proposed for diminishing the first of these errors (mirrors, floats, &c.).   With the necessary practice, the parts of one subdivision of the measuring vessel may be estimated to within about one-tenth of a division (the error is about ± 0·1), and in all cases it may easily be estimated to within a quarter of a division.

* *Chemiker Zeitung*, vol. xii. p. 494.

† *L'Orosi*, vol. x. p. 109; *Chemisches Centralblatt*, vol. xviii. p. 559; Fresenius, *Zeitschrift für Analytische Chemie*, 1888, p. 642.

‡ *Journal of the Chemical Society*, vol. xlvii. p. 116.

Other errors result from the adhesion of the liquids to the sides of the vessel, and also in the way they are allowed to flow out, the mere reference to which will suffice.

γ. *Omitting to take into Consideration the Reduction of the Weights to Vacuo.*—According to the principle of Archimedes, every body which is plunged into a liquid or gaseous body loses so much of its weight as is equivalent to the weight of the body it displaces. This naturally leads to errors in the results of weighings; and although in many cases these are so slight that they need not be considered, yet occasionally they reach such an important amount that it appears desirable to take them into consideration.

For ordinary atmospheric conditions (height of barometer, temperature, degree of humidity), for the reduction of the weights to vacuo, the following formula holds good :—

$$P = p \left[1 + 0{\cdot}0012 \left(\tfrac{1}{s} - 0{\cdot}12\right)\right],$$

in which P is the weight in vacuo, p the weight on the balance, and s the specific gravity of the body to be weighed. It is assumed in this that the weights were of brass (specific gravity, 8·4).

Some examples may serve to show the differences between the weights in air and in vacuo :—

For ignited ferric oxide (specific gravity 5·12) the formula shows $P = p\,(1 + 0{\cdot}000096)$, that is to say, a difference in weight of about 0·01 per cent.; for alumina, which has been heated to redness, with a specific gravity of 3·85, the formula yields $P = p\,(1 + 0{\cdot}000168)$, a difference in weight of 0·017 per cent.; for magnesium pyrophosphate, specific gravity 2·40, $P = p\,(1 + 0{\cdot}00036)$, or a difference of 0·036 per cent.; and, finally, in the case of silica, specific gravity 2·20, $P = p\,(1 + 0{\cdot}000396)$, that is to say, a difference of about 0·040 per cent.

While, then, in almost every case no correction need be made for ferric oxide and alumina, in the two last cases mentioned under certain conditions somewhat important differences may result, as, for instance, about 0·01 per cent. in the analysis of magnesite, of 0·036 per cent. for calcined magnesite, and of 0·006 per cent. in the analysis of a ferro-silicon with 14 per cent. of silicon.

If platinum weights are used for the weighing, as is usually

the case with the small quantities of substances commonly used for analysis, the differences become somewhat larger. The reduction formula is then $P = p [1 + 0.0012 (\frac{1}{s} - 0.05)]$, and one obtains therefore in the cases above given the following results:—Ferric oxide, $P = p (1 + 0.00018)$; difference in weight $= 0.018$ per cent.; alumina, $P = p (1 + 0.00025) -$ difference in weight $= 0.025$ per cent.; magnesium pyrophosphate, $P = p (1 + 0.00044) -$ difference in weight $= 0.044$ per cent.; silica, $P = p (1 + 0.00048) -$ difference in weight $= 0.048$ per cent. The analysis differences are consequently as follows:—In the case of magnesite $\Delta = 0.013$ per cent.; with calcined magnesite, 0.044; and with 14 per cent. ferro-silicon, 0.007 per cent.

The errors induced by this are, it is true, not very important, but they deserve to be considered in accurate work, especially in the presence of other sources of error which are similar in their effects, such, for instance, as the very marked solubility of magnesium pyrophosphate.

These conditions must, however, also be considered from another point of view. As a rule, the weights used for quantities exceeding one gramme are of brass, but of platinum for fractions of a gramme, and finally the riders are made of aluminium. If these weights are entirely concordant in air, this is not true of their weights as reduced to vacuo. As a rule, the weighings of the original substance, if they exceed one gramme, are, however, made with brass weights, but in the subsequent weighings of the much smaller quantities to be dealt with during the course of the analysis, platinum weights are employed. The result is that the total weight of the several constituents can never agree exactly with the weight originally taken for the analysis, which in reality it ought to do.

δ. *Not taking into Consideration Volume Correction.*—The errors due to this in the measurement of gases are so great, that in the case of gases the correction ought never to be overlooked. But even in the case of standard solution, overlooking this question of the volume correction may lead to unpleasant errors, as, for instance, is shown by the following table drawn up by A. Schulze:—*

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* Fresenius, *Zeitschrift für Analytische Chemie*, 1882, p. 167.

Normal.

Temp. Degs. C.	Oxalic Acid.	Hydro-chloric Acid.	Nitric Acid.	Sulphuric Acid.	Sodium Carbonate.	Caustic Soda.	Water in Glass.	Temp. Degs. C.
5	+0·0018	+0·0017	+0·0026	+0·0025	+0·0026	+0·0028	+0·0009	5
6	17	16	25	24	25	26	9	6
7	16	15	23	22	23	24	9	7
8	15	14	21	21	21	22	9	8
9	14	13	19	19	19	20	8	9
10	13	12	17	17	17	18	8	10
11	12	11	15	15	15	16	7	11
12	10	9	13	13	13	14	7	12
13	8	8	11	11	11	11	6	13
14	7	6	9	9	9	9	5	14
15	5	5	6	6	6	6	3	15
16	3	3	4	4	4	4	2	16
17	1	1	1·	1	1	1	1	17
17·5	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	17·5
18	−0·0001	−0·0001	−0·0001	−0·0001	−0·0001	−0·0001	−0·0001	18
19	3	3	4	4	4	4	2	19
20	6	5	7	7	7	7	4	20
21	8	7	10	10	9	10	6	21
22	10	9	12	12	12	13	8	22
23	13	12	15	15	15	16	10	23
24	16	14	18	18	18	19	12	24

This table, which relates to the normal solutions mentioned at the temperature of 17·5° C., gives the correction for one cubic centimetre of the solution. The correction is therefore made by adding the product of the number of cubic centimetres used with the factor given in the table—observing whether it is a − or + quantity—to the number of cubic centimetres of the standard solution added in the course of the determination. Supposing, for instance, a titration had been made at a temperature of 12° C., and that 21 cubic centimetres of normal sulphuric acid had been used, then $21 + 21 \times 0.0013 = 21.0273$ cubic centimetres is the correct quantity of 17·5° C. If, on the other hand, 21 cubic centimetres at the temperature of 24° C. was necessary, then $21 − 21 \times 0.0018 = 21 − 0.0378 = 20.9422$ c.c. of acid at a temperature of 17·5° C. If, again, a titration with normal sulphuric acid were effected once at a temperature of 12° C. and, again, at 24° C., and 19·974 c.c. were used in the one case and 20·036 c.c. in the other (both of which exactly represent 20 c.c. normal sulphuric acid at 17·5 C°.), and no correction had been made for the temperature, the two determinations would then show a difference of $\frac{100(20.036 − 19.974)}{19.974} = 0.31$ per cent.

e. Errors which may be caused by the Adhesion of the Liquids to the sides of the containing Glass Vessels.—These must be taken into consideration, both in the marking and in the use of the measuring vessels. Measuring flasks, for instance, must be marked for their actual contents, burettes and pipettes, however, for the solution as run out, that is to say, in such a way that the solution as run out shall correspond with the value shown by the division. Some of the solution will still remain, however, attached to the glass sides, the quantity being dependent on the degree of fluidity and adhesion of the liquid. This, with adequate time allowed, drains together again, so that, when titrating, one should wait about two minutes between every reading. In the case of pipettes, the quantity of solution that flows out is most constant when the point of the pipette is placed in contact with the side of the vessel, and subsequently wiped off on it.

In addition to these sources of error, the temperature also influences the quantity of solution that will flow out, as is shown by the following short table given by Mulder:—*

Temperature of the Pipette and of the Normal Solution.	Plus or Minus Quantity in Thousandths which flowed from the Pipette.		Quantity in Thousandths, according to the Difference in the Expansion of the Normal Solution and of Glass.	Gay-Lussac Correction.
	L.	II.		
5° C.	+ 0·55	+ 0·57	+ 0·725	+ 0·1
10°	+ 0·40	+ 0·44	+ 0·500	+ 0·2
15°	0	0	0	0
20°	− 0·70	− 0·72	− 0·750	− 0·6
25°	− 1·74	− 1·75	− 1·775	− 1·6

4. *Errors in the Operations.*—These include the unavoidable losses in the analysis, the action which results from the glass and porcelain vessels being attached, the variations in the ash contents of the filters used, &c. In this connection some of the numerous researches relating to these points may be referred to. According to R. Cowper,† when the following solutions, in quan-

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* Mulder, *Die Silberprobirmethode.*

† *Journal of the Chemical Society*, 1882, p. 254.

tities of 100 c.c., are heated for six days in glass vessels to 100° C., the following amounts of glass are dissolved :—

Reagent.	Glass dissolved in 100 cubic centimetres. Gramme.
Water	0·0080, 0·0100
Sulphuretted hydrogen water	0·0125, 0·0087
Dilute ammonium sulphide (prepared from 0·982 sp. gr. ammonia)	0·0496, 0·0525, 0·0512
Concentrated ammonium sulphide (prepared from 0·88 sp. gr. ammonia) . .	0·0340, 0·0472
Ammonia of 0·982 sp. gr.	0·0258, 0·0425
Concentrated ammonia, 0·88 sp. gr. . . .	0·0075, 0·0077

R. Weber and Sauer [*] boiled various solvents in 100 c.c. flasks, made of different kinds of glass, replacing constantly the liquid boiled away, and obtained the results as shown on p. 99.

Porcelain vessels are, as a rule, much less attacked.   Thus R. Fresenius found that when the solvents named were boiled in Berlin porcelain dishes, the quantities dissolved, expressed in per cent. of the solvents, were as follows :—

Solvent.	Quantity dissolved.
Water	0·0005
Pure hydrochloric acid	0·0053 and 0·0047
Ammonium chloride solution of 10 per cent. strength	0·0393
Crystallised sodium carbonate solution of 10 per cent. strength	0·0243

Unfortunately, other firms place upon the market porcelain dishes which are very considerably attacked even by concentrated hydrochloric acid.

5. *Errors in the analytical methods* belong to the most important causes of differences in analytical results.   They are so numerous and various, that it must suffice to mention a few examples.

To these belong the incomplete oxidation of carbon in its determination with the aid of chromic acid and sulphuric acid;

* *Zeitschrift für angewandte Chemie*, 1891, p. 662 ; *Berichte der deutschen Chemischen Gesellschaft*, vol. xxv. pp. 70 and 1814.

Percentage Composition of the Various Glasses.

Variety of Glass	1	2	3	4	5	6	7	8	9	10
Silica	76·22	74·09	76·39	68·56	74·48	74·69	66·75	74·12	77·07	74·40
Alumina	—	0·40	0·50	1·85	0·50	0·45	1·31	0·50	0·30	0·70
Lime	4·27	5·85	5·50	7·60	7·15	7·85	13·37	9·55	8·10	8·85
Potash	—	7·32	4·94	2·24	6·64	8·64	15·50	4·86	3·75	4·40
Soda	19·51	12·34	12·67	19·75	11·23	8·37	3·07	11·97	10·78	11·65
Totals	100·00	100·00	100.00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Silica : lime : alkali	17 : 1 : 4	11 : 1 : 2·6	127 : 1 : 2	10 : 1 : 3	9·5 : 1 : 2	8·8 : 1 : 1·6	4·5 : 1 : 0·8	8 : 1 : 1·6	8·8 : 1 : 1·5	8 : 1 : 1·5

Loss of Weight in Milligrammes of a 100 c.c. Flask by the action of

Variety of Glass	1	2	3	4	5	6	7	8	9	10
Water, 5 hours.	62·5	31·5	29·5	17	13	9·5	7·5	7·5	·5	4·5
H_2 SO_4, 25 per cent, 3 hours	?	43·5	35	8	7	6·5	5·5	5	5	3
HCl, 12 per cent, 3 hours.	85	?	21	4	2·5	1·5	1	1	0	0
NH_3, 10 per cent, 3 hours.	?	?	62	11	8·5	7·5	7·5	6	5	5
Sodium phosphate, 2 per cent, 3 hours	?	?	81	64	40	35·5	34	30	15	12·5
Sodium carbonate, 2 per cent, 3 hours	283	160	130	124	50·5	45	42	42	26·5	25

leaving out of consideration the various forms of the carbon in the Eggertz' colorimetric method for the determination of carbon; the sulphur losses, which in all methods for the determination of sulphur that depend on the evolution of sulphuretted hydrogen, result from a portion of the sulphur remaining in the insoluble residue; the error in the manganese assay with lead peroxide due to the ready decomposability of $HMnO_4$, and many others.

I would like just to point out in this connection that these errors may be of a positive as well as of a negative character, that consequently a method where, under certain circumstances, two or more simultaneously occurring inaccuracies exactly counterbalance each other may give very satisfactory results, while in other cases it may leave much, very much, perhaps, to be desired, a circumstance which must be taken into consideration in the testing of analytical methods.

Thus, to select a widely-known instance, barium sulphate is not altogether insoluble in ferric chloride, and results would be obtained which would be too low if, in the determination of sulphur, after its complete oxidation to sulphuric acid, it were precipitated with barium chloride in the solution containing ferric chloride. On the other hand, the precipitate obtained in this case is not pure, as it always contains included iron salts in smaller or larger quantity, and this again leads to too high results. In certain circumstances both these sources of error may more or less exactly counterbalance each other, while in others one or the other may get the upper hand, and the result consequently be either too high or too low, as the case may be. Indeed, A. Tamm * has based on this circumstance a rapid method for the determination of sulphur.

These occurrences—and they are not always so simple as in the above example—necessitate the most complete investigation, if with certainty either all errors are to be avoided or the most complete possible balance of errors effected, which in many cases leads to exceedingly useful methods.

6. *Personal Errors.*—The errors, too, which are due to this cause are of great importance, especially where the analyses are

* *Jernkontorets Annaler*, 1887, p. 4.

not effected by trained chemists, but their intimate study is beset with great difficulties. To effect this, a series of parallel analyses should be made by different chemists, using the same method, and with exact and detailed specifications as to the method of working, and as a result in all probability "personal equations" would be obtained, such as have long been known to astronomers.

These personal errors, which have their origin partly in the particular skill of the one or the other in different methods and operations, partly in personal estimations, as in the colorimetric methods, or in other causes, are, however, of particular interest, because it is just these which lead one chemist to prefer one method and another a different one, and not infrequently cause opinions as to one and the same method to be very different.

To these personal errors various occurrences may be referred, as, for instance, the following, mentioned by C. B. Dudley: *— In a sample of steel Drown found 0·14 per cent. of silicon, while on the other hand another chemist found 0·28. A further investigation showed that the first-named chemist had allowed the dish to stand for two days after evaporation and taking up again with water, and had only then filtered off the silica. It was found that the silica had slowly passed into solution again. After two days of 0·28 per cent. of silica only 0·14 was present, and after six days only 0·06, a behaviour which would not have been anticipated.

7. *Errors caused by differences in the calculation of the analyses based on the atomic weights.*

During recent years a series of revisions of the values of the atomic weights have been published, but unfortunately they do not in all cases present the desired agreement among themselves. As, in cases where the greatest possible accuracy is required, it appears only natural to employ these revised values in the calculation of the analyses, it may not be superfluous to discuss them in detail.

The oldest of these new determinations is that of F. W. Clarke.† This was followed in 1883 by the work on the " Atomic

* *Journal of Analytical and Applied Chemistry*, 1893, p. 5.
† Constants of Nature, 1882.

Weights of the Elements " by L. Meyer and K. Seubert, whose statements, like the previous ones of Clarke, have found the widest circulation in technical circles. In 1886, Van der Plaats [*] published the results of his new determinations, and, lastly, in 1893, F. W. Clarke [†] undertook a revision of the values of the atomic weights, previously published by him. As the last values have not yet been generally adopted, his older results must here also be taken into account. The atomic weights of the elements of greatest importance in the iron and steel industries, as set forth in the works cited, are as follows:—

Element.	F. W. Clarke, 1882.	L. Meyer and K. Seubert.		Van der Plaats.		F. W. Clarke, 1893.
		Atomic Weight.	Possible Error.	Atomic Weight.	Possible Error.	
Chromium	52·009	52·45	0·5–1·0	52·3	0·3	52·1
Iron .	55·913	55·88	0·1	56·0	0·05	56·0
Magnesium	23·959	23·94	0·5–1·0	24·4	0·05	24·3
Manganese	53·906	54·80	0·5–1·0	55·0	0·1	55·0
Phosphorus	30·958	30·96	0·1	30·95	0·05	31·0
Oxygen .	15·9633	15·96	<0·5	16·0	...	16·0
Sulphur .	31·984	31·98	<0·5	32·06	0·01	32·06
Silicon .	28·195	28·00	0·5–1·0	28·0	0·1	28·4
Barium .	137·763	136·86	0·5	137·1	0·1	137·43

From this the following figures are calculated for some of the more important compounds:—

* Annales de Chimie et de Physique, Series 6, vol. vii. April.

† Journal of the American Chemical Society, vol. xvi. p. 179 ; Chemisches Central-blatt, 1894, No. I. p. 810.

Compound.		Clarke, 1882.	L. Meyer and K. Seubert	Van der Plaats.	Clarke, 1893.	Maximum Difference per Cent.	Remarks.
Ferric oxide Fe_2O_3	Fe_2 O_3	111·826 47·8899	111·76 47·28	112·0 48·0	112·0 48·0		
	Fe_2O_3 1 pt. by wt. $Fe_2O_3=$ pt. by wt. Fe	159·7159 0·70016	159·64 0·70008	160·0 0·70000	160·0 0·7000	$\Delta_{1-3}=0·02$ $\Delta_{2-4}=0·01$	
Barium sulphate $BaSO_4$	S O_4 Ba	31·984 63·8532 136·763	31·98 63·84 136·86	32·06 64·00 137·10	32·06 64·00 137·43		
	$BaSO_4$ 1 pt. by wt. $BaSO_4=$ pt. by wt. S	232·6002 0·13750	232·68 0·13744	233·16 0·13750	233·49 0·13730	$\Delta_{1-2}=0·04$ $\Delta_{3-4}=0·14$	
	1 pt. by wt. $BaSO_4=$ pt. by wt. Ba	0·58797	0·58819	0·58801	0·58859	$\Delta_{2-1}=0·04$ $\Delta_{4-3}=0·10$	
Magnesium Pyrophosphate $Mg_2P_2O_7$	Mg_2 P_2 O_7	47·918 61·916 111·7431	47·88 61·92 111·72	48·8 61·9 112·0	48·6 62·0 112·0		This difference is 0·4 per cent. with pure magnesite, with burnt magnesite it amounts to 1·12 per cent.
	$Mg_2P_2O_7$ 1 pt. by wt. $Mg_2P_2O_7=$ pt. by wt. Mg	221·5771 0·21626	221·52 0·21601	222·7 0·21913	222·6 0·21833	$\Delta_{3-2}=1·44$	
Chromium oxide Cr_2O_3	Cr_2 O_3	104·018 47·8899	104·90 47·88	104·60 48·00	104·2 48·0		Difference with a 50 per cent. ferrochrome=0·15 per cent.
	Cr_2O_3 1 pt. by wt. $Cr_2O_3=$ pt. by wt. Cr	151·9079 0·68474	152·78 0·68661	152·60 0·68545	152·2 0·68462	$\Delta_{2-4}=0·31$	
Silica SiO_2	Si O_2	28·195 31·9266	28·0 31·92	28·0 32·0	28·4 32·0		Difference with a 14 per cent. ferrosilicon=0·10 per cent., but with pure quartz = 0·73 per cent.
	SiO_2 1 pt. by wt. $SiO_2=$ pt. by wt. Si	60·1216 0·46897	59·92 0·46729	60·0 0·46667	60·4 0·47019	$\Delta_{4-3}=0·73$	

If, in the titration of manganese (by the chlorate method), with ferrous ammonium sulphate and permanganate, the manganese value of the permanganate standard is calculated from its iron value, one atom of manganese corresponds with two atoms of iron. The corresponding atomic weights are then as follows :—

	Iron.	Manganese.
Clarke, 1882	55·913	53·906
L. Meyer and K. Seubert	55·88	54·8
Van der Plaats	56·0	55·0
Clarke, 1893	56·0	55·0

Thus, one part by weight of iron represents—

According to—	Parts by Weight of Manganese.
Clarke, 1882	0·48205
L. Meyer and K. Seubert	0·49033
Van der Plaats	0·49107
Clarke, 1893	0·49107

The maximum difference is—

$$\Delta_{3-1} = 1\text{·}87 \text{ per cent.}$$
$$\Delta_{4-3} = 0\text{·}15 \text{ per cent.}$$

or, with an 80 per cent. ferromanganese, 1·5 or 0·12 per cent.

The atomic weights cited above demand attention, however, from another point of view. For example, L. Meyer and K. Seubert give the possible error in the atomic weights of chromium, magnesium, and silicon, as 0·5 to 1·0; this means that analyses, in respect of these elements, may possibly be incorrect to the extent of $\frac{50}{52}$ to $\frac{100}{52}$, $\frac{50}{24}$ to $\frac{100}{24}$, and $\frac{50}{28}$ to $\frac{100}{28}$, or about 1 to 2 per cent., 2 to 4 per cent., and 1½ to 3 per cent. respectively. It is evident, therefore, that a thorough revision of the atomic weights in question is urgently needed.

8. *The want of homogeneity of the sample* is one of the most important sources of error. It deserves most special attention in any case where it is a question of exhaustively testing analytical methods, since it is only when there is absolute certainty of the actual homogeneous composition of the material used in the parallel analyses that it is possible to obtain a trustworthy judgment upon the methods used.

This want of homogeneity of the sample is met with, however, in various ways. It is mostly shown in the varying composition of an ingot at the base or at the top, externally or internally. These are liquation phenomena, the results of which are very clearly shown in the following results of investigations by Snelus. From an ingot measuring 19 by 19 by 84 inches, which was allowed to cool extremely slowly, he cut sections 4

inches above the base and 21 inches below the top, perpendicular to the axis, and from each of these sections he took six samples, No. 1 being at the corner, and No. 6 at the centre of the plate. The analyses gave the following results :—

No.	Top Plate.			Base Plate.		
	Carbon.	Silicon.	Phosphorus.	Carbon.	Silicon.	Phosphorus.
1	0·44	0·032	0·044	0·44	0·048	0·060
2	0·54	0·048	0·060	0·42	0·058	0·062
3	0·57	0·080	0·086	0·41	0·048	0·054
4	0·61	0·096	0·097	0·40	0·048	0·048
5	0·68	0·120	0·111	0·38	0·048	0·058
6	0·77	0·187	0·142	0·37	0·048	0·052

This want of homogeneity must obviously, also, be met with in the products obtained by cutting or rolling such ingots. Thus Eccles found that soft plates, of which the fracture at the two exterior sides was silky and in the centre granular, had the following composition :—

	Granular Layer.	Silky Portion.
	Per Cent.	Per Cent.
Carbon	0·160	0·115
Phosphorus . . .	0·112	0·038
Sulphur	0·070	0·030
Manganese . . .	0·570	0·576

A sheet 30 millimetres thick had the following composition :—

	Top End.				Bottom End.			
	Exterior.		Interior.		Exterior.		Interior.	
	Longitudinal Section.	Cross Section.	Longitudinal Section.	Cross Section.	Longitudinal Section.	Cross Section.	Longitudinal Section.	Cross Section.
Carbon . . .	0·240	0·240	0·320	0·400	0·250	0·250	0·250	0·200
Sulphur . . .	0·025	0·017	0·061	0·070	0·028	0·030	0·022	0·031
Phosphorus . .	0·050	0·052	0·100	0·088	0·060	0·070	0·060	0·052
Manganese . .	0·160	0·150	0·088	0·140	0·120	0·110	0·120	0·120

A. R. von Dormus * gives the following interesting analyses of steel rails :—

No.	Point at which Sample was taken.	C.	Si.	Mn.	P.	S.	Co.
358	Surface . .	0·411	0·011	0·477	0·063	0·026	0·130
,,	Centre of head .	0·525	0·007	0·506	0·104	0·038	0·126
,,	Neck . .	0·485	0·010	0·506	0·099	0·040	0·123
,,	Base . . .	0·456	0·009	0·488	0·064	0·025	0·109
4185	Surface . .	0·396	0·013	0·500	0·063	0·033	0·131
,,	Centre of head .	0·480	0·014	0·494	0·089	0·041	0·152
,,	Neck . .	0.456	0·009	0·500	0·079	0·037	0·130
,,	Base . . .	0·472	0·014	0·511	0·076	0·035	0·110
363	Surface . .	0·357	0·010	0·412	0·057	0·039	0·122
,,	Centre of head .	0·501	0·006	0·430	0·099	0·057	0·139
,,	Neck . .	0·507	0·011	0·430	0·102	0·063	0·126
,,	Base . . .	0·459	0·014	0·407	0·063	0·033	0·105
4275	Surface . .	0·297	0·012	0·442	0·028	0·018	0·134
,,	Centre of head .	0·504	0·016	0·500	0·062	0·048	0·152
4164	Surface . .	0·387	0·008	0·494	0·027	0·017	0·134
,,	Centre of head .	0·441	0·007	0·506	0·046	0·027	0·137
5469	Surface . .	0·351	0·028	1·146	0·045	0·019	0·140
,,	Centre of head .	0·681	0·023	1·239	0·084	0·021	0·135

Portions immediately adjacent may, however, also exhibit a very variable composition. This is well known in the case of the carbon percentage of cement steel and of manufactured steel (being in the former greater at the surface, and in the latter less than in the interior), in the case of graphite (especially in mottled pig iron), and in that of slag (notably in weld iron). Other elements, such as manganese, phosphorus, and especially sulphur, may also, however, in certain circumstances, be very unequally distributed.† In the case of phosphorus determinations by eight different chemists, in one and the same pig iron, the highest result was about double as great as the lowest. In a pig iron, sixteen chemists found, as is shown by the following figures,‡ from 0·005 to 0·024 per cent. of sulphur, and the very highest and lowest of these results were obtained by chemists of high repute :—

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* *Zeitschrift des Oesterr. Ingenieur und Architekten Vereins*, 1896, Nos. 13, 14, 15.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, p. 159.

‡ *Journal of Analytical and Applied Chemistry.*

|	Sulphur per Cent.
(a.) Aqua regia method	0·005
(b.) Absorption and oxidation with bromine, treatment of the insoluble residue with aqua regia, barium sulphate precipitate weighed	0·008
(c.) Absorption and titration with normal iodine solution .	0·009
(d.) Method not specified	0·010
(e.) Absorption in alkaline solution of lead nitrate and weighing the precipitate as barium sulphate . .	0·011
(f.) Aqua regia method; the solution was allowed to stand twenty-four hours after the addition of barium chloride	0·012
(g.) Aqua regia method	0·012
(h.) Absorption in potassium permanganate solution, and weighing the barium sulphate precipitate . .	0·013
(i.) Absorption in cadmium solution and titration with normal iodine solution	0·013
(j.) Potassium permanganate solution and barium sulphate weighed	0·013
(k.) Aqua regia method. Neutralised with ammonia. Precipitation of barium sulphate and allowed to stand for twenty-four hours	0·013
(l.) Absorption in cadmium chloride solution and titration with normal iodine solution	0·015
(m.) Absorption and titration with normal iodine solution .	0·017
(n.) Absorption in potassium permanganate solution and weighing the barium sulphate	0·017
(o.) Volumetric analysis (details not specified) . . .	0·019
(p.) Absorption in cadmium sulphate and titration with normal iodine solution	0·020
(q.) Aqua regia method	0·021
(r.) Absorption in caustic soda solution and titration with normal iodine solution	0·022
(s.) Aqua regia method	0·024

As I also had frequently met with very considerable differences in the sulphur contents of the same sample of steel, I took from a cut piece of sheet iron, 30 millimetres broad and 6 millimetres thick, the high sulphur percentages of which permitted the weighing out of small samples, sixteen samples in the manner shown in Fig. 1, and with each two sulphur determinations were made so as to show that the differences were not due to the methods employed.   The results were as follows :—

XIII.	IX.	V.	I.
0·058 } 0·053 0·048	0·053 } 0·056 0·060	0·095 } 0·093 0·090	0·092 } 0·092 0·092

XIV.	X.	VI.	II.
0·043 } 0·039 0·034	0·058 } 0·060 0·062	0·070 } 0·072 0·074	0·086 } 0·082 0·076

XV.	XI.	VII.	III.
0·057 } 0·053 0·049	0·042 } 0·038 0·035	0·075 } 0·080 0·085	0·095 } 0·097 0·098

XVI.	XII.	VIII.	IV.
0·042 } 0·037 0·032	0·080 } 0·085 0·090	0·075 } 0·082 0·088	0·053 } 0·053 0·053

The greatest difference between two pairs of determinations amounted to 0·013 per cent. (sample viii.), and that at a place in which very varying sulphur contents adjoin each other (iii. with 0·097, iv. with 0·053, and xi. with 0·038 per cent. of sulphur); whilst the maximum difference between all the sixteen mean analyses was 0·060.

The irregularity of the distribution is shown in Fig. 2.

In a large quantity of samples of filings, irregularities in the composition of the material are exhibited by the differences in the analytical results. These are of so local a nature that they

FIG.I.

UNDER — 0·05 PER CENT OF SULPHUR
0·05 — 0·065 % S
0·065 — 0·085 % S
ABOVE — 0·085 % S
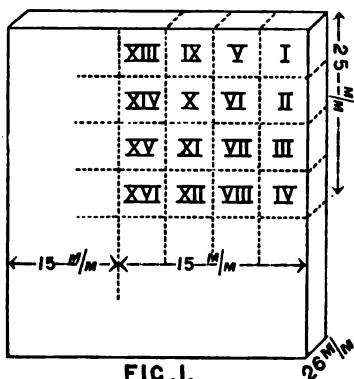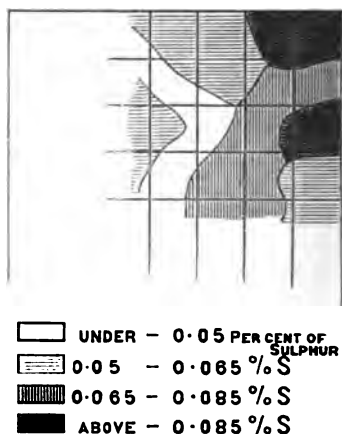
FIG.2

can only be detected under the microscope. The brittle parts of the material give finer filings than those which are more tough. The former must consequently collect at the bottom of the vessel that serves to receive the sample, more especially when it is violently stirred with the object of ensuring the best possible mixing.

A very interesting series of observations bearing on this point have been published by L. Schneider.* The only source of regret is that the two portions of the material were not analysed separately. The results were as follows :—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1894, p. 244.

No.	Steel.	Laminated Residue, per Cent.	Pulverulent Residue, per Cent.	Percentage Composition.								
				C.	Si.	P.	S.	Mn.	Cu.	W.	Cr.	Ni.
1	Nickel steel	99	1	0·42	0·22	...	...	0·22	...	...	...	6·0
2	Filings from a foreign steel sample	99	1	0·46	0·15	0·04	0·01	0·48	0·08	...	...	...
3	Krupp tool steel	98	2	0·90	0·28	0·02	0·01	0·26	0·05	0·11	...	...
4	St. Egyd steel	96	4	0·67	0·37	0·04	0·05	0·23	...	...	...	...
5	St. Egyd steel	92	8	1·20	0·35	0·02	0·03	0·23	...	...	...	...
6	Puddled steel	94	6	0·90	0·17	0·02	0·01	0·11	...	...	...	...
7	Witkowitz steel a	90	10	0·15	?	...	...	...	...	...	...	...
8	Witkowitz steel b	90	10	0·08	?	...	...	...	...	...	...	...
9	Chrome steel	90	10	?	...	...	...	...	...	...	0·95	...
10	Zeltweg steel	90	10	0·30	0·02	0·09	?	0·20	...	...	...	...
11	Neuberg steel	90	10	0·52	0·36	0·15	0·06	0·39	0·18	...	...	...
12	Open-hearth steel from Donawitz	89	11	0·20	0·04	0·08	?	0·13	...	...	...	...
13	Chrome steel	85	15	1·45	0·31	0·01	0·02	0·42	0·03	...	1·00	...
14	Neuberg steel	78	22	0·56	0·44	0·08	0·05	0·47	0·10	...	...	...
15	Riffle steel	78	22	1·24	0·81	0·02	0·02	0·21	...	1·90	...	...
16	Open-hearth steel a	69	32	0·13	0·02	0·08	0·04	0·47	0·03	...	...	...
17	Open-hearth steel b	68	40	0·14	0·02	0·07	0·03	0·17	0·01	...	...	...
18	Kibiswald puddled steel	66	34	0·90	0·08	0·02	0·02	0·13	...	...	...	...
19	Tungsten steel from Kapfenberg	60	40	2·07	0·70	0·03	0·01	0·54	0·01	6·13	...	...
20	Böhler tool steel	50	50	1·20	0·20	0·03	0·02	0·12	...	...	...	...
21	Crucible steel	32	68	0·83	0·08	0·03	0·02	0·31	0·04	...	2·50	...
22	Neuberg tungsten steel	5	95	2·60	0·34	?	0·01	?	0·01	6·40	0·10	...
23	Mushet steel	0	100	2·24	0·99	0·04	0·02	1·56	tr.	6·26	0·22	...

In sample No. 13, the laminated portion contained 1·0 per cent. of chromium, and the powder contained 0·7 per cent. The comminution of steel samples is effected by means of hammering. In the figures given in columns 3 and 4 in Nos. 16 and 17, there appears to be a misprint in the original, as the total exceeds 100.

The behaviour is the same with graphitic grey pig iron, especially in metal average analyses. Thus, I found [*] in an average sample of spiegeleisen, in nine determinations, variations in the manganese contents between 6·3 and 13·3 per cent., an observation which was confirmed by J. Kail [†] for other elements.

To avoid these difficulties, not only must the irregular distribution of the elements in iron and steel materials be closely

[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1890, p. 273.

[†] *Ibid.*, p. 506.

studied, but also some agreement must be arrived at as to the method of taking the samples. In this last connection I would like to submit the two following proposals :—

(*a.*) *That it is best entirely to exclude average samples of metals.* In the majority of cases it is much better to examine a number of separate samples, and to calculate the average from these results. Not only in this way may a satisfactory agreement be arrived at between the various samples, but a good idea is also obtained of the variations in composition of the material under investigation.

(*b.*) *In the case of grey or mottled pig iron,* in the determination of carbon, only so much of the metal should be broken down as is necessary for the test; that is to say, the whole of the powdered material is to be used up in the determination.

It is scarcely necessary to point out that all solutions used should be thoroughly mixed, whether these are solutions of the samples or standard solutions.

The detailed consideration of the sources of error in chemical analyses will have shown, even to non-chemists, that chemical analysis, especially that of steel, is by no means a simple matter, and that it is necessary to place it in the hands of skilled chemists if it is a question of obtaining accurate results. Is, however, such a degree of accuracy always necessary? To answer this question, the various uses to which analysis is put must be considered. One must distinguish between (1) analyses which are intended for use in controlling the work at the works ; (2) trade analyses; (3) analyses which are to show the reason why the material under examination possesses certain properties, or whether it is suitable for certain definite purposes ; (4) analyses connected with scientific investigations, where it is a question of ascertaining the constitution of iron materials, and the investigation of the relations existing between their chemical composition and their physical properties, &c.

For the purposes of works control, relative accuracy is adequate ; that is to say, the method must not only show a plus or minus of the substance to be determined, but also with equal contents give good agreement, at least in all cases which may occur in the locality in question. It is desirable that these results should agree as nearly as possible with the true percentages, but this is

a secondary matter as compared with the necessity of making as many as possible of these determinations simultaneously, and in the shortest time.

Such a method, for instance, is the well-known Eggertz colori-metric method for the determination of carbon. This gives results which are quite adequate for work control purposes in all cases where the material of the sample is produced under similar conditions as to hardening. Under no circumstances, however, can it be adopted if it is a question of the simultaneous examination of unhardened, hardened, and annealed steel, or of foreign steels whose methods of manufacture are not exactly known.

A second example is the phosphorus determination by the molybdate method by the aid of the rotation apparatus. It gives results which are perfectly satisfactory if all conditions as to its use are *exactly* complied with, and the point taken into consideration that the calculation factor varies with the volume of the precipitate. It follows that this method can be well recommended not only for works control purposes, but generally. Yet by slight variations in the manipulation the method gives differences which are so great that it can only be entrusted to trustworthy hands, even if it is only a question of works control analyses.

In the case of commercial analyses, to which also those analyses belong that are intended to ensure that the percentage limits of chemical composition required by contract are maintained, it is only possible to be content with this kind of requirement when both parties, the buyers and the sellers, have agreed to some method for the determination of each particular substance. Under certain conditions, therefore, it is possible to rest satisfied with *relative accuracy* even in trade analyses ; but, as a general rule, it is best to aim at the highest possible degree of accuracy.

The question is quite different in the instances given under (3) and (4). Here the requirement of endeavouring to attain a maximum degree of accuracy takes the foremost place, while the possibility of making many determinations rapidly and at the same time is not so important.

It is therefore necessary to distinguish between—(*a.*) *Methods for works control*, and, under certain circumstances, for trade

purposes; and (*b.*) *Methods for all other purposes.* With regard to these latter, I should like to draw attention to one other circumstance. Modern methods of analyses, such as are actually employed daily in practice, are, with almost the single exception of the determination of graphite, complete analyses. Iron materials are, however, in no way homogeneous substances such as minerals, but are mixtures of various compounds, analogous, that is, to rocks composed of several minerals, and there can be no question but that many samples of iron of quite identical elementary composition, according to the kind and quality of their inner components, may show altogether different physical properties. It has so far only been attempted to explain this in a few cases. At the present time the different forms of carbon are more intimately known, but practical methods for their determination suitable for use in the technical laboratories are wanting. With reference to certain other elements, phosphorus,* chromium,† tungsten,‡ and others, some information has been given, but the notes referred to are very isolated in character, and consequently require confirmation by numerous investigations before general conclusions can be drawn from them. We know that all elements which can be precipitated by sulphuretted hydrogen are completely contained in the residue insoluble in dilute sulphuric acid;§ that copper separates out in the iron mass in the form of metallic shots or as sulphide; that phosphorus is partly evolved in the form of phosphuretted hydrogen by dilute acids, but that it in part remains undissolved‖ as iron phosphide or manganese phosphide, Fe_3P or Mn_3P_2; that slag is included in the metal, &c., &c.

It is just these kinds of investigation, however, which are of especial value, not only from a scientific point of view, but to an eminent degree for technical practice; for it is only when a more accurate knowledge is obtained of the inner constitution of the

* L. Schneider, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1886, p. 736; H. von Jüptner, *Ibid.*, 1894, p. 209.

† H. Behrens and Van Linge, *Fresenius' Zeitschrift*, vol. xxxiii. p. 573; H. von Jüptner, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, No. 2.

‡ L. Schneider, *Oesterreichische Zeitschrift*, 1885, No. 18.

§ F. G. Müller, *Stahl und Eisen*, 1888, p. 293; Reinhardt, *Ibid.*, 1889, p. 405; Von Reis, *Ibid.*, 1889, p. 720.

‖ H. von Jüptner, *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1894, p. 208.

varieties of iron met with in practice—and methods are known by which in every case this may be readily and accurately determined—that it will be possible to choose for every purpose a material of proper chemical composition and mechanical treatment, and to find means and ways in order to prepare it with certainty for every case. In this connection not only must chemical examination be adopted, but microscopic as well, a method which so far does not receive nearly the amount of attention it deserves.

In view of what has just been discussed, the questions to be considered—as I showed at the recent international conference for the unification of testing methods at Zürich—may in their general scope be briefly sketched out as follows:—There require to be studied—(1.) The irregular character of the samples, and some agreement as to the method of taking the samples, must be arrived at, both as regards these irregularities and also any impurities introduced in the course of their being broken down to size. (2.) At least all the more important methods of determination for all the constituents met with in iron and steel materials, including slag and gas inclusions, should be thoroughly studied and compared with one another, taking into consideration all possible sources of error. We can then either rest satisfied with this comparison or pass to the setting up of standard methods. In any case, it will be necessary to distinguish between methods for the works control, &c., in which, in the first instance, rapidity of completion has to be considered, and which may be defined as works assays, and the analytical methods required for every other purpose in which accuracy is the main requirement. (3.) We must not confine ourselves to determinations of the various elements, but must direct our attention to such matters as permit of the various forms and combinations in which the several constituents can occur in technical varieties of iron, being distinguished and quantitatively determined.

In view of all that has been said above, it follows that the scope of the necessary inquiry is of an extremely wide character. It is so wide, indeed, that it is scarcely desirable to attempt the solution at the same time of all the questions requiring consideration. It would be better, perhaps, to endeavour to solve these one after the other, and to rest contented at first with the fol-

lowing: (1) Investigations relating to the want of homogeneity in the samples, and to some decision as to the method of sampling ; (2) examining the methods for the determination of the main constituents, that is, say, of carbon, silicon, manganese, sulphur, phosphorus, copper, and slag.   (3) Since, moreover, as has been pointed out, the value of the atomic weights on which the analytical calculations are based have at least in certain cases considerable influence on the results, it is desirable to arrive at either an agreement, perhaps temporary in character, as to the values to be adopted, or else to revise the atomic weights necessary in connection with the methods under examination.

To arrive at a general agreement of the methods to be examined, it would appear desirable, from the very commencement, to lay down definitely the general principles which are to be adopted.   Much that has to do with this has been already shown, so that I may confine myself to a few brief remarks on this point.

It must not be forgotten that we have to consider, in the first instance, practical work, and that even for our scientific purposes, which we also wish to place at the service of practical work, very tedious or troublesome methods have no value, or at most but very little.   In this case too it is usually not so much the question of a single analysis, as of analytical material wide in scope that has to be the basis for further study.

But even for theoretical purposes, other conditions being equal, simple methods appear more desirable than more complicated ones, for every operation introduces sources of error ; the greater the number of operations necessary and the longer these take, the greater both in number and in degree are the errors to which the analyst is exposed.

Permit me to give an example.   The following method for the determination of phosphorus was proposed :—The phosphorus is to be precipitated from a nitric acid solution as ammonium phosphomolybdate, the precipitate collected on a filter, dissolved, precipitated with magnesia mixture, filtered, again dissolved, and finally titrated with uranium acetate.   Why was not the phosphomolybdate, or at least the magnesia precipitate, weighed direct ?

That we have to distinguish between works assays and precise

analytical methods has been already pointed out.   It is naturally advantageous, however, for a method to possess at the same time both the valuable properties of assay methods and of scientific methods, and consequently to be suited to both purposes.

It must not be forgotten that skill, personal factors, exceptional or other circumstances, may cause one analyst to prefer one method and another a second.   This is a circumstance which it seems to me should be considered, to reduce personal errors to a minimum, and I should therefore consider it desirable that for every element many methods, based on as widely differing facts as possible, should be tested, and both their relative and their absolute accuracy ascertained.

It may here be pointed out that it can be by no means our aim to arrange normal methods, which are to be used always, under all conditions, and at all times.   On the contrary, it must be left to every chemist to work as he thinks best, and the progress which scientific knowledge is making must also be taken into consideration, a progress that now-a-days is enormous.   On the other hand, as has been pointed out, our aim must be to arrange for as many different methods as possible, and to ascertain their relative conditions of value.   These methods are to serve as standard methods in investigating the particular method used by any individual analyst, or new methods, and are always to be used when differences in the results of analyses made at different laboratories have to be explained.   But to be in accord with scientific progress, any other methods which may from time to time be proposed must be all included in the scope of the investigations.

DISCUSSION.

Mr. G. J. Snelus, Vice-President, said they were very much indebted to the author for his paper. He had read it through carefully, as it was a subject in which he had taken a great interest. Furthermore, he had been asked to act on the International Commission, and he had agreed to do so. Having read the paper, he felt that they were in the hands of a first-class leader. Dr. Wedding, the new Bessemer Medallist, was the next leader on the Commission, and he firmly believed that it would have important results. There had been a great many Commissions before. He had had the pleasure of acting on one for the British Association. There had also been the American Commission. These Commissions had added a good deal to our knowledge ; but there yet remained much to be done. He had quite recently had experience on this point, in a case where the question of sulphur came into dispute ; the differences between well-known analysts were remarkable. This point had been recently investigated in Scotland by a young chemist, and a very admirable paper had been written upon it, with the publication of which his pupil, Mr. Paul, had had a great deal to do. The paper before the Institute was a very valuable one upon this particular branch of the subject. What they wanted was, to have more work, more facts recorded, and better methods devised ; and he believed that the paper would have a great deal to do in laying a foundation for truly scientific methods in the analysis of iron and steel, which they must all admit to be the foundation of the Institute, for without the analysis being correct, they could draw but very imperfect conclusions, and they depended entirely upon analysis to guide them in their working methods.

Professor Roberts-Austen, C.B., Member of Council, said that, as President of the British Association Commission, he should like to thank Baron Jüptner for his admirable paper. He could not lay claim to any accurate manipulative knowledge of the analysis of any metal other than gold ; and that was probably

the reason why they made him President of the Commission.
They had had the advantage of the co-operation of some very
distinguished men—Sir Frederick Abel, Mr. Riley, Mr. Spiller,
Mr. Snelus, Dr. Tilden, and Mr. Turner—and although he had
no direct manipulative knowledge, as he had said, he had tried
to keep himself abreast with current literature, and he was es-
pecially indebted to Baron Jüptner's writings.   He appreciated
thoroughly the admirable work which had been done by the
author of the paper, and in the name of the British Associa-
tion Commission begged leave sincerely to thank him.

Dr. WEDDING said that perhaps the members would be in-
terested in hearing something about the resolution which was
carried by the Conference at Zurich in September 1895, when
Baron Jüptner and himself were nominated to undertake the
preliminaries necessary for the creation of an International Com-
mission for uniform chemical methods for conducting the analysis
of iron.   It was considered advisable that eminent chemists of
every nation, and particularly those who knew what was neces-
sary for the practice of ironworks, and had been engaged in analysis
of iron, should be nominated as leaders of the different depart-
ments; that is to say, for all important ingredients in all sorts
of iron.   They had, therefore, asked Englishmen, Americans,
Frenchmen, Austrians, Swedes, &c., and they had received
answers from a sufficiently large number of them intimating that
they would be glad to undertake the work as leaders of different
departments.   His friend Mr. Snelus, amongst others, had kindly
given his services.   Each one, they thought, was to have a
certain element in preference.   For instance, one would take
phosphorus, another sulphur, and so on ; and each would examine
all that had been recorded in the literature of his particular sub-
ject, and work it out.   As the work was honorary, each leader
would have one or more analysts to help him ; and as those
analysts must be paid, money was necessary.

But, besides, they thought it very necessary to establish a
laboratory at Zurich—an international place against which no
nation could have any objection—and which would stand perhaps
best under the guidance of Baron Jüptner, who would there get
together all the work that had been done by the various gentle-

men, and try to decide what was best. That was thought to be the best way to bring into accordance all the results of the different persons and methods.

As this head—or control—laboratory had no other purpose than to examine the present and future methods of analysis of iron, it ought to ,produce the best possible results. It was calculated that in about a year's time for the purpose £3000 would be wanted, half of which, namely £1500, would be necessary for the laboratory in Zurich, the other half for assistant chemists. That was not a very large sum. There were perhaps 300 large ironworks in the world, and if the iron industry prospered as it had been doing, he did not think it would be too much to ask the owners of those 300 ironworks to contribute £10 a year. It might be necessary for them to undertake to contribute for at least ten years, and they would then be able to see how matters stood, and whether it was necessary to pay for the next ten years more or less for the same purpose. That was the plan which had been proposed. A communication had been drawn up and sent to the Council at Zurich at the hands of Mr. von Tetmajer, and an answer was shortly expected as to the further development of the scheme. He should very much like to know whether the plan, of which he had just given a rough sketch, met with the approval of the members of the Institute.

The CHAIRMAN said he thought there ought to be no difficulty in getting £3000 from the various works, as had been suggested by Dr. Wedding. It would mean £10 a piece, and he should be very pleased to forward his contribution.

Mr. J. E. STEAD, Member of Council, said that he had read the paper very carefully indeed, and he considered that every works chemist should be supplied with a copy of it. He should advise them to read every word with the greatest care and attention, because there was not a word too much in it—in fact when they had finished the paper they were sorry that it was finished, and that there was not a great deal more of it. Mr. Brough, their secretary, had not read all the points out to them, and probably it would not be well to discuss the paper, as there

were so many other papers to consider. He had been asked to
act as one of the leaders of this International Commission, and
he was glad to hear that Mr. Snelus had consented to occupy
a similar position.

There was one thing which he thought they ought to lay to
heart in the iron trade, and that was that in order that their
chemists might be as intelligent and as up to date in the
knowledge of all methods of analysis in the work done all over
the world, there ought to be some technical libraries in all their
industrial centres, so that the chemists and engineers, and other
persons in connection with the works, might go there to con-
sult and find what other people in the world were doing. The
International Commission would in time do away to a great
extent with the necessity for such a library ; but members must
have noticed, in passing through Continental laboratories, that in
these laboratories the chemists were supplied with books and
technical literature upon the points which it was their duty to
know. In the works in this country it was not so, and he
thought that it was a very important thing that English chemists
should not be allowed to go on in the rule-of-thumb way which
had been followed in the past, but should be educated and
encouraged to be intelligent creatures instead of rule-of-thumb
workers. It was unfortunate that the latter was very much the
case in many of the laboratories in this country. He hoped
that the result of the paper would be to do away with that
condition of things. He knew that in some of our works, and
many important works too, the head chemists actually did not
receive £100 a year, and yet they were expected to keep up with
the times ; which was utterly impossible. The men were, in
fact, overworked. There was no encouragement to study ; and
there was not any surplus money to enable such a chemist
to become a member of any society, or to subscribe to and
buy the literature of the day. He did really hope that the
paper would result in a change in that direction. He felt per-
fectly certain that the International Commission, when its reports
were completed, would be a huge advantage to the members of
the iron and steel trade, and, therefore, they had to thank the
author for his very valuable work.

Professor J. O. ARNOLD said that he had not followed the reading of the paper quite so closely as he should have done, having seen it for the first time that morning.   As far as he had read it, it seemed to be a paper of the greatest value, and to touch upon points of vital importance to steelworks.   He would suggest that the Commission should devote their close attention to the question of segregation.   He had some very remarkable cases lately, which showed that segregation was very much more common and took place in very much smaller masses of steel than was usually supposed ; indeed, he knew of a case of a tire, in which the sulphur in the centre of the tire was 0·1 per cent., and on the outside of the tire—within about 1¼ in. of the centre—the sulphur was 0·043.   That, of course, was a very serious difference.   He thought that, even in casting small ingots, if they were cast very hot, it was quite possible to get in those ingots a serious liquation which would often account for the difference between analyses which was usually put down to differences between the analysts themselves.   He should like to have spoken more fully on the question, but the paper wanted very careful reading first, and he therefore could only suggest that great attention should be paid to the matter of segregation.

Mr. R. A. HADFIELD, Member of Council, thoroughly supported the views of Professor Arnold and Mr. Stead, and it might be interesting to the latter to know that in Sheffield, at the Technical School there, there had already been formed the nucleus of a metallurgical library ; in fact that school was much indebted to the Council of the Iron and Steel Institute for their support of this question, in the fact that they sent, without any charge, copies of the Institute *Journal*.   The whole subject dealt with by Baron Jüptner was of the greatest importance to those concerned in the management of iron and steel works, as any agreement which could be come to for more trustworthy and systematic analyses added greatly to the efficient control of those who were responsible for the quality of the various products.   There was one point which Baron Jüptner might add to his paper, and that was, that when taking samples for analysis it was very advisable to specify their condition and their last previous thermal treatment.   As regarded carbon steel specially this was of the greatest

importance, as if this information was not given the various figures obtained could not sometimes be considered of service.

As regarded the question of noting the condition of the sample, there was an illustration in the paper. There was there given a list of twenty-three specimens, but no idea was conveyed as to how the samples were taken—from bars, plates, or other forms. As far as possible, therefore, all chemists should, when making chemical examination, insist upon having the full history of the sample being tested, whether from cast or forged material, the size of the specimens, and the position from which the drillings were taken. Mr. Hadfield believed if these suggestions were adopted considerable questioning would be saved on the part of those who had to consider and determine the effects of the various elements composing such sample.

Dr. S. RIDEAL said he had not much to add to the statements of previous speakers on the important subject under discussion. He thought that the iron and steel industry was somewhat behind other allied industries in getting official and standard methods of analysis. He thought that this was no doubt due to the fact that although the literature was very voluminous and complete, they had not had a commission on the lines proposed by Dr. Wedding and Baron Jüptner up to the present time. The British Association Commission, although consisting of a very able body of men, were left practically to themselves to examine one or two processes and to determine the analysis of the standards by those processes. What was really wanted was a laboratory such as was proposed at Zurich, where there would be trained analysts who would go over all the existing methods which seemed at all accurate, and report as to which of those methods was the most satisfactory when worked by the same chemist. At present, not only was there a want of uniformity in the methods, but the personal equation frequently led to a conflict of opinion, and therefore, when a sample was analysed by different men, it was often impossible to say which method was the best. If the methods were worked through by a trained man and fully reported on, their relative merits would then be known and these difficulties would be solved. With regard to the older elements, the labour involved in such an inquiry,

owing to the large amount of literature, would be considerable; and even with the newer elements which were being used at the present time, like nickel, aluminium, and chromium, the literature was so enormous that this work could not be done by private enterprise. He had recently had occasion to look into the methods for the analysis of chromium in steels, and he had found altogether that from thirty to forty different processes had been proposed even for the determination of that comparatively new element in steels. It was impossible for a single individual to work through those thirty or forty different processes and decide which of them was the best; so that any opinion which a chemist formed on a particular process for the determination of such an element, really represented the individual author's opinion on those one or two processes which he had had time to look into a little more closely.

Mr. GEORGE AINSWORTH desired to say a word with regard to the suggestion that Mr. Stead had made. He quite agreed with what had been said as to the status of works chemists, and the necessity of their keeping up with the current literature of the day on the various methods of analysis. But when Mr. Stead said that it was desirable that there should be technical libraries in each centre for the advantage of the works chemists, he did not quite see how that was going to answer what was required. What was the good of a technical library to a works which was miles away from everywhere, as some of the works were? He thought that more might be done by the Institute in gathering together, tabulating, and circulating information generally. Listening on the previous day to the report, he was rather surprised to find what a large amount of money the Institute was accumulating, and he was induced to ask what it was all for. They had a lot of investments, he presumed selected by Sir David Dale principally, and if so he had not the slightest doubt that they had very much appreciated since they were made, and he thought that some of the money might be spent with advantage by the Institute employing a larger staff of abstractors to epitomise the different publications relating to methods of analysis, and either enlarging the Journal or publishing the abstracts as a separate volume. He

thought that would be very much more to the advantage of the Institute than technical libraries in certain centres. It might possibly be arranged for this to be done by some of the chemists proposed to be employed on the Commission, who could also report on what was being done in conjunction therewith. He ventured to suggest that if that were considered by the Council, and something done in that direction, the money would be spent advantageously and for the benefit of the trade and the members generally.

The CHAIRMAN said his office was now to ask the meeting to accord a vote of thanks to the author of the paper. He would take the opportunity of repeating, as had been done so well by those who preceded him, his conviction with regard to the value of the paper. He was one of those who were in the position of looking at the question, not as an owner of works, but as a railway director—a body of course which had to deal with the material supplied by the works in their own neighbourhood. He had been struck, and very much disappointed, he admitted, by the very great discrepancy in the analytical results that he had received in the last three months. It should be remembered that in steel all the foreign matter was comprised within about $1\frac{1}{2}$ per cent. Speaking roughly, the steel turned out by the steelworks of the country contained something like $98\frac{1}{2}$ per cent. of iron, or pretty nearly that amount. When they considered that that $1\frac{1}{2}$ per cent. was productive of such a marked difference in the quality and character, and therefore in the value of the steel turned out, it became a matter of the utmost importance that the best methods should be made known to all those concerned for determining the relative quantity of each ; because it was not a simple mixture of one substance with steel, but it was a mixture of half a dozen, and they did not know how far the existence of one might modify the effect produced by another. All those things, of course, had to be taken into account.

With regard to segregation, a subject mentioned by Professor Arnold, he entirely agreed with him. There was the utmost difference in the composition of an ingot. He had recently had an ingot carefully analysed by Mr. Stead himself, and by others, and

there were certain differences amongst those chemists; but the effect upon the constitution of the steel, and the quality of the rails rolled from the same ingot, was something very remarkable. Public attention had recently been called to the failures of rails. About this perhaps more had been said than the necessity of the case required, but they could not be too careful, and he for one should be very glad to further to the utmost of his ability any such organisation as had been referred to by his friend Dr. Wedding. He thought there was a good deal of sound sense in what had fallen from Mr. Ainsworth. That was not the first time that he had said the same thing. He thought that part of the £8000, which was accumulating apparently for the benefit of their successors, should be expended in getting immediate results for the generation now in existence. He should most willingly, so far as he was concerned, give his consent to the devotion of a very considerable portion of the money for the purpose in question. He would conclude his remarks by moving a vote of thanks to the author of the paper.

The vote of thanks was carried by acclamation.

CORRESPONDENCE.

Mr. BERTRAM BLOUNT drew attention to the following points arising from a consideration of the paper. The impurity of re-agents alluded to by the author was a common cause of error. So difficult was it to obtain hydrochloric and nitric acid of the requisite degree of purity, that he was in the habit of redistilling the whole of that used in his own laboratory. Errors of measuring were often of serious magnitude. Except for the division of solutions in which the total material to be determined bore a small ratio to the volume of the solution, it was undesirable to employ a pipette or burette, however carefully calibrated, without some method of checking its indications. In his opinion there was only one accurate method of measuring solutions and subdividing them, and that was by weight.

He entirely agreed with the author that differences in analytical

results by different chemists frequently arose from want of identity of the samples, arising from the lack of homogeneity of the material sampled.   This difficulty was best met, and, at the same time, a considerable amount of additional information could be obtained, by the method mentioned by the author, viz., the analysis of a number of separate samples from the same piece of metal. But although this was feasible and desirable in scientific or technical investigations, it was impracticable in ordinary analytical work.   The time and cost represented by an adequate number of separate determinations were prohibitively great.   It remained, therefore, to take all reasonable precautions to ensure substantial identity of sample taken from one or several pieces of massive metal.   With ingot iron and steel such identity was not unattainable, and with cast metal containing graphite, disseminated through a metallic matrix, the suggestion of the author that the whole of the material broken down should be used for a single determination was undoubtedly valuable.   He (Mr. Blount) had, on occasion, used a method proposed some years ago for sampling cast iron borings by moistening them with absolute alcohol (free from residue on evaporation), and taking portions of the moist mass of approximately the weight needed, drying and reweighing accurately.   The portions thus weighed would contain their correct quota of graphite, which was otherwise liable to segregation by reason of the large difference between its specific gravity and that of the cast metal from which it was derived.

One other point might be mentioned as being of considerable importance, and receiving, on the whole, a smaller amount of attention than it deserved.   It was that in the case of the analysis of puddled iron (and in smaller degree of ingot iron) discrimination should be made between the impurities present as enclosed slag, and those existing in the metal itself.   This would probably be best effected by an ultimate analysis of the metal and enclosed slag, followed by the isolation of the slag by one of the conventional methods, and the analysis of the material thus separated.   A distinction could then be drawn between, for example, phosphorus existing in the mass of the metal and actively harmful, and that which formed a constituent of the slag and was comparatively innocuous.   For all such improvements in existing analytical

processes steady systematic work was requisite, the cost of which might reasonably be borne by those most keenly and immediately interested, namely, the iron and steel manufacturers.

Mr. W. GALBRAITH thought that it was by no means clear what Baron Jüptner meant by "standard methods of analysis;" because he commenced by stating that the phrase "was strictly speaking a catchword," later, that "considerable objection might be raised against the introduction of standard methods for general use"; and he ended by saying that "it must be left to every chemist to work as he thinks best." He was not at all surprised at the Baron finding a difficulty in defining his position, because he was quite sure the more it was inquired into, the greater its difficulties and the more undesirable the use of such standard methods would appear. He did not propose to go into the question of the sources of error, which were many, but were not always the fault of the analyst. He would, however, plead for a little more encouragement to chemists to investigate their processes, and that they should be given a free hand in inquiring into any discrepancies. The objections to any standard methods were many. It would tend to lessen personal responsibility, because a young chemist might fairly argue that as he had gone through the "standard" method, his results must be trustworthy. But the fatal objections were its cost and impracticability. A committee appointed for the purpose would require to investigate nearly every process suggested, and as the "standard" methods would be perpetually changing, would require to be permanent. Imagine a committee investigating the methods of determining chromium these last five years. A committee could not possibly keep up with the progress. Further, it would be difficult to decide where such a committee's work should begin and end. If it was only a question of half a dozen elements, say in steel, it might be comparatively easy, but iron and steel manufacturing now embraced a great number of alloys, and was likely to still further go in that direction; and these, again, involved such a large variety of ores, slags, &c., that the work would be exceedingly comprehensive. Further, would the committee be expected to devise methods, or decide between rival ones? The writer of the paper stated that "it must

be left to every chemist to work as he thinks best," but it must be apparent that it would be difficult to do so, and that a chemist who did not adopt the recommended or standard method would be placed at an enormous disadvantage, especially in the event of a dispute.   The probability was that a young chemist in such a case would be instructed to work according to the standard method.   In the direction of accuracy and speed there had been very great progress made recently, and a great deal of time and energy had been spent in bringing this about; witness the investigations made in the methods of determining sulphur, chromium, and phosphorus.   In certain cases, however, where the investigations were of an expensive character, the Iron and Steel Institute might profitably spend a little money in carrying out such an inquiry, and it might do a great deal in collecting what information there was, and what inquiry had been made abroad as well as at home, even if a small charge was made for it, and possibly sold or published separately from the Proceedings; and indeed the Institute might with advantage do this separately with the engineering, practical, and chemical sides of the manufacture of iron and steel.   The collection of such information would, he thought, save a great deal of unnecessary work being done; and a committee or committees appointed for this purpose would, he thought, do far more good than anything in the shape of a tribunal for setting up " standard " methods.

Mr. G. S. PACKER thought that Baron Jüptner had placed them under great obligations for the very able and lucid manner in which he had marshalled the difficulties in the way of obtaining unification of analytical results, and with what Baron Jüptner had said he was in agreement.   He was pleased to see that in considering a remedy, or remedies, he placed want of homogeneity as the first point requiring to be dealt with, as it was manifest that the value of having standard methods would be very seriously detracted from if the samples dealt with were not uniform.   In the case of ores, &c., this difficulty could be fairly got over in sampling, but not so readily in the case of masses of metal.   On that portion of his subject the Baron might justly have laid more stress than he had done, the differ-

ences in composition which he mentioned in his paper being
frequently considerably exceeded.   Mr. Stubbs had been the
first to call attention in a public manner, by a paper read
before the Institute, to the action which went on in masses of
steel during solidification in the mould, resulting in great differ-
ences between the top and bottom of ingots, and between the
centre and the outside ;   but a further serious difficulty in
the way of obtaining coincident results was the action of local
segregation which might take place at any part of an ingot, even
quite close to the bottom, and giving rise to variable differences
in composition.

He himself had come across an extreme case in which the
sulphur had varied from 0·05 per cent. to 0·18 per cent. (sulphur
being the most variable impurity present in steel), and phosphorus
from 0·04 per cent. to 0·10 per cent., in adjacent portions from
near the bottom of an ingot, together with other similar instances
of the same action in a smaller, but still considerable degree, and
more than confirming the results given in the paper.

The difference between indifferently made metal such as that
and the most carefully made, was one of degree only, and as an
instance of that he might mention that in a steel carefully made
from pure materials, in which the sulphur contents were down to
0·012, a well-marked case of local segregation had occurred near
the bottom end, showing plainly under the microscope at the low
power of 45 linear (the sulphur in this portion not being deter-
mined for want of sufficient material for both chemical and
microscopical tests).   Hence he had no hesitation in saying that
the discrepancies in results which had occurred between careful
analysts were due to a greater extent to want of uniformity in the
metal than to errors made by the analysts themselves.   It was
the usual custom (in Great Britain at any rate) to put down all
differences in results to errors of analysts, an idea strengthened
by some chemists themselves who argued from insufficient
knowledge, overlooking or not paying sufficient attention to
non-uniformity.

In works where a large output was one of the chief factors,
there was not the time available to allow of attention to all the
details which reduced that action to its minimum, and as a
consequence uniform results would be difficult to obtain.   He

apprehended it would prove to be a difficult matter to induce such works, turning out good merchantable steel and capable of fulfilling practical requirements as they did, to incur the expense of endeavouring to make it chemically uniform.

The method of working described would much increase the work of a laboratory and consequently its staff, but the doubt arose as to whether the results to be obtained would be commensurate with the extra work involved. For instance, in a mass of metal in which the analyses from different portions differed, it would be necessary to know the weight of metal which each analysis represented before it would be possible to work out a trustworthy average. That could not be obtained by actual weighing, nor could it be obtained in a satisfactory manner by measurement, and it would therefore be left to the knowledge and judgment of the person taking the sample, so that the "personal equation" would still come into play. It appeared to him that a sample ladled out of the steel when finished would more nearly represent the metal; at any rate he had found that to be the case.

Mr. JOHN PARRY considered that practical, hard-working foremen of works and those immediately under them were apt to attach very little importance to the ordinary chemist's work. The many reasons for that could not be discussed here, but, as all knew who had been connected with the manufacture, the feeling was a very natural one, and not without some foundation. However that might be, the results had not been very satisfactory.

The practical man and the chemist had between them, by a sort of mutual antagonistic reaction, brought the business of accurate chemical testing into some discredit. The Baron's summary of what was and what ought to be done deserved to receive prompt attention. That applied more especially as regarded the present system, where all classes of chemical work were mixed up indifferently.

Research work, and indeed any kind of chemical analysis of importance, should be distinctly divided from ordinary assay work for works use. Even the latter could only be of use when trained experts were employed. The ordinary assay methods for the test-

ing of steel, &c., were apparently simple and easily understood, but the technical skill required for prompt and accurate work could only be acquired by long practice under careful supervision. If that were the case, how necessary it must be with very important works to secure the services of a scientific chemist, and give him proper facilities, together with leisure for the due performance of his duties.

In his own work (Parry and Morgan) on ironworks' analysis (*Industries*, 1893) and appliances therefor, he had as a matter of fact drawn attention to the necessity of a proper division of the laboratory, advocating a separate department for accurate work, also favouring the adoption of simple methods and avoiding the use of complicated apparatus and methods, which were worse than useless in inexperienced hands.

In that connection he had noted that young chemists had developed a liking for complicated methods. That was in his . opinion a mistake. He did not think that each chemist should be allowed to pursue his own course entirely, although there was something to be urged in favour of that. On the whole, however, it might for commercial use be better to accept the methods which had been carefully examined and approved by a committee of competent chemists. Thus at any rate relatively correct results comparable with each other might be obtained. Of course such methods should always be open to criticism, and be modified in accordance with increased knowledge.

He also noted a most important article by Baron Jüptner on the relations between the chemical and the physical qualities of iron and steel. The Baron acted on the supposition that each atom, as one constituent of the iron, exercised the same influence as an atom of the other constituents; 12 parts by weight carbon equalled in every respect 28 silicon or 54·8 manganese, as follows:

Carbon.	Silicon.	Manganese.
8	7	14

The author remarked that that reminded him of Professor Roberts-Austen, who had insisted on the due consideration of the atomic volumes of the foreign elements in steel, as well as the actual percentage weights given, from a study of which he (Mr. Parry) was led

to suggest (South Wales Institute of Engineers) that the constituents of steel should be given both in percentage weight and atomic volumes. It was quite obvious that both meant the same thing, but the latter was probably more accurate, and might yet prove of use in elucidating some doubtful points with respect to the effect of carbon, manganese, &c., when alloyed with iron.

Mr. JOHN PATTINSON, Newcastle-upon-Tyne, thought that Baron Jüptner had supplied ample evidence of the want of uniformity in the work of even experienced and eminent analysts in the analysis of iron and steel when working on the same sample, and he had given an excellent *résumé* of the many causes which might account for that want of uniformity. When it was considered how seriously even minute quantities of certain substances affected the physical properties of iron and steel, it was obviously necessary that chemists should have it in their power to determine the amounts of those substances with the greatest accuracy before their influence could be carefully studied and ascertained. Those exact methods were all the more necessary when specified amounts of certain substances were stipulated for in sale contracts of iron and steel. An organisation such as the International Commission suggested by Baron Jüptner and Dr. Wedding would be of great service in hastening the time when the best methods of securing exact analyses would be made known to all chemists engaged in the manufacture and analysis of iron and steel throughout the world. There was an immense amount of work for such a Commission to do, and most of this work had been well pointed out by Baron Jüptner. In addition, he would suggest that an important part of its work would be to describe methods of preparing pure iron and manganese compounds, and possibly other compounds of exact and known composition, for use in checking the accuracy of laboratory tests and for making standard solutions. It was no easy task to make such compounds, and they were of the greatest value.

When the most accurate methods of analysis were known, it would still remain with the buyers and sellers of raw materials and manufactured goods to see that these methods were prescribed in their contract notes. Unless that was done the older and incorrect methods would probably still continue to be used.

The inaccuracy and irregularity of the Cornish assay for copper in copper ores had been very forcibly pointed out, and more correct methods of analysis described by the late Dr. Percy thirty-five years ago; but notwithstanding this, the incorrect Cornish assay was still the one used for buying and selling most of the copper ores used in Great Britain!

Mr. C. H. RIDSDALE considered that the subject of the paper was one which was constantly exercising the minds of all chemists, particularly works chemists, whose results were usually judged according to the manner in which they agreed with those of a public analyst; in the case of any disagreement theirs being assumed as a matter of course to be wrong. He did not wish there to enter into a discussion as to the relative merits of the case, but the author deserved the thanks of all works chemists for pointing out so clearly the very much greater difficulties and the different conditions under which they had to work, necessitating the use in most cases of quicker methods. At the same time, he should be sorry if from this defence they drew the inference that works chemists' results were necessarily or generally inferior, as, despite the considerations named, they could and did do a great deal of very high-class work. The fact of the matter was a works chemist should, and in a great many cases did become a specialist. The mere fact of getting out vast quantities of work in a short time did not necessarily imply bad work.

There were three kinds of methods—those in which, in the desire for speed, the quantities dealt with were so small and the operations so hurried and devoid of precautions, that they were many of them little or no better than eye indications or rough practical tests. Again there were those in which, whilst striving at accuracy, so many and tedious complications were introduced as in most cases to defeat their own end, as they could not be safely put into the hands of ordinary assistants such as not only works chemists but public analysts also had to make use of; and after all the bulk of the work done in all laboratories had to be done by assistants. Lastly, there were the class of methods midway between these two, fairly simple, modified to suit the kind of materials most dealt with, but not cumbered with too many precautionary complications, each of which presented large possi-

bilities of error.   It was these last which were generally employed by chemists who bore in mind that there was something even better than speed.

The large quantities of work that were turned out so quickly were due to—

1st. Careful organisation.

2nd. Much of the work being of a similar kind and coming in at fairly regular rates, or at anyrate there always being plenty, so that there were no slack times.

3rd. Each process being studied, and such parts as can be without detriment (as, for instance, those dependent purely on manipulative skill) hastened.

In the North-Eastern Steel Company's laboratory they were turning out about 100,000 analyses per year, but it was not done by using the very shortest methods.   There were many of these which tempted them in vain, despite promises of higher speed, as the dominant idea they kept before them was that work to be of use must be accurate, that bad results were worse than no results.   He quite agreed that it was a matter of indifference by what method results were obtained so long as they were correct, and that theoretically it was objectionable to limit the freedom of the individual.   But the main point to bear in mind was that ninety-nine out of every hundred analyses (by whoever made) were for commercial purposes, and it was of infinitely more importance to the commercial world that results should agree, even if this involved the adoption of standard methods, than to have a freedom which conduced to the want of uniformity at present met with.   Thus it mattered very little to the steelmaker or the engineer whether the percentage of some impurity present was really 0·05 per cent. or 0·06 per cent. so long as both agreed as to how much it was and what its effect was.   At present, what a works chemist really had to do was not to aim at giving what *he* believed to be the most correct result, but to work so as to agree with the chemist who was appointed referee for each particular contract, and against whose decision there was no appeal. Consequently he established a relation between the referee's results and his own, and found that, say : A generally made his carbons " right," but his phosphorus results 0·01 per cent. " too low," and his sulphurs 0·015 per cent. " too high " ; B made his

carbons 0·04 per cent. "too high," his phosphorus "right," his silicons " too low "; and so on with C and D, &c., and also with the various bodies which the works chemist had to test against them. The differences were no doubt to a large extent due to the methods used, and would be correspondingly reduced by the adoption of standard methods. But the worst of it was that A, in the search after truth, altered his methods frequently, and got results differing altogether from what he had obtained hitherto, and which amounted to altering the specification to be worked to by 0·01 or 0·02 per cent.

Now, though it was exceedingly improbable that any commission would ever be able to make it compulsory to adopt its methods, it was highly probable that engineers would soon recognise its good work, and specify that materials should have a certain composition, "as tested by International Commission Method No. 157." These standard methods, with every detail minutely described, should be printed and sold like the blue-books of the Patent Office, and both referee and works chemist could then obtain and work to them, and the latter would have the satisfaction of knowing that they would not be changed at each new idea that the referee got. At the same time, there would be no real hindrance to progress, as new methods would be continually investigated ; and when, but not until there were real grounds for superseding a method, it would be officially cancelled and its substitute published, notification of this being given in the official weekly or monthly publication of the Commission.

Again, it would be a great advantage to all chemists in another way. At present there was an immense mass of methods published in the various chemical journals, and it was impossible for any one busy chemist to even read carefully, to say nothing of thoroughly testing every one of them. Smith, Jones, and Robinson each published a method almost exactly similar, Brown made some trivial alteration and read a long paper on it, and it took valuable time to wade through these things, most of which was time wasted. But if it became a principle before publishing a method to submit it to the Commission, giving full particulars of wherein its advantages were supposed to lie, what reactions were involved, and what was considered new about it, they

would thoroughly test it, and if it was of any value publish an unbiassed report on it.

Further, if those carrying out the investigation were in ignorance of the identity of the author, and all methods not possessing a distinct advantage were ruthlessly condemned, the work would be the more valuable. Such methods would as it were be "hall marked," and the credit reflected on the inventor would be proportionately greater; whilst there would be no need for chemists to spend so much time examining methods which proved useless, and more could be given to studying those recommended by the Commission. For his part, he would much prefer, if he brought out a new method, to submit it in this way.

Again, the methods could be classified, *e.g.*, "tedious, but very accurate, suitable for the highest scientific work where time is no object;" or "simple, fairly accurate, suitable for commercial purposes," &c., and the time, weak points, tendency to high or low results, together with any special remarks be given. Also there could be published a clear summary, followed by far fuller and more minute details and experiences than are at present obtainable generally. In fact, the whole of the information supplied would be systematised, which in itself would be an immense advantage.

Further, the Commission could deal in a similar manner with the question of taking and preparing samples, so that engineers could not only specify a certain standard method, but that the samples should be taken and prepared, say, "as described in Clause 123." This question was perhaps of more importance than that of the adoption of standard analytical methods, and it alone, he thought, would tend far more to the "unification of results" than the removal of all the errors (to the extent to which they are generally found), described under the heads 3, 4, and 7 in the paper. In fact, it was probable that the trouble that segregation gave to the chemist in this direction was its most serious effect, and far more harmful than its effect on the materials themselves. In deciding upon standard methods of sampling, &c., it must not be forgotten that if they were too elaborate they could not be adopted generally, as—to quote their own case again—with the number of analyses cited, their transport and preparation alone was no small matter, and they should

avoid such methods as, by their cumbersomeness, would not only involve considerable expense, but *delay* in obtaining results, and there was hardly any commercial purpose for which the question of time could be considered a matter of indifference. If he seemed to take a practical though possibly lower view of the question in preference to an ideal one, it was because he held that if they were to make science of practical use they would have to move with the times, and serve commercial ends by studying how to attain accuracy without unnecessary complications, and without sacrificing speed, and this was in the main right, not only for the works chemist but also for the public analyst.

Mr. ALEX. E. TUCKER regretted that Baron Jüptner disparaged, in the opening sentences of his paper, the expression "standard methods," as the establishment of officially recognised methods of analyses in metallurgical works was most desirable, and certainly the want of uniformity of methods must precede want of uniformity in the results obtained. He thought the question of standard methods was a most important one, and one which might fitly come under the supervision of the Iron and Steel Institute. In the first place, in view of the enormous amount of routine work now done in iron and steel works laboratories, it was necessary to employ intelligent lads, who could not be considered chemists, but who nevertheless were able to carry out instructions faithfully, and by whom therefore a recognised method should be pursued. A second reason for pressing for officially recognised methods was found in the perplexing difficulties which an analyst had to face on account of the huge number of processes which were scattered throughout technical literature, most of which were perfectly valueless, and could not have been fairly tested by the authors describing them. Indeed, many books, specially devoted to analytical methods, were in existence which gave processes which could not fail to give incorrect results. That very serious fact would be met by the establishment of standard official methods. The introduction of these official methods would, however, of course take time, and would present difficulties—firstly, because with the continual advancement of science,

codicils, as it were, would from time to time have to be added to them; and secondly, the leading analysts of the day had in many cases their special methods, which they would probably be reluctant to give up or to modify. Baron Jüptner did not seem to sufficiently recognise the difference between works analyses and those obtained by properly qualified chemists.

In works it was generally of the first importance to obtain results rapidly, and for the attainment of that some accuracy might be sacrificed. Thus they heard of silicon, sulphur, and phosphorus being determined within half-an-hour of the taking of the metal from the furnace. Results were obtained within 10 per cent. of the truth, and such information was of the highest value in the economy of the steelworks using the metal. Again, colour testing in high-carbon steel was very valuable, but its inaccuracy was well recognised. In such work, where accuracy was sacrificed to rapidity, the absence of accuracy should be well recognised, as there was at present an undoubted tendency to rush the work and claim accuracy at the same time; the fault lay largely in classing together all samples, instead of dividing them for slow and accurate and rapid and rough analyses. An example of this defect had come under Mr. Tucker's notice recently, where, in the laboratories of one of the wealthiest and largest chemical companies in the world, the purity of the limestone used was determined by the displacement of water in a bottle marked by a strip of paper. No correction was made for the solubility of the evolved carbonic anhydride, or for temperature, or for barometric pressure, yet the results obtained were considered good enough for their purpose, and controlled large consignments of limestone. Of course, where such results were considered good enough, it was not necessary, or even desirable, that the operations involved should be conducted by chemists. It could not be expected of analysts that they should undertake such routine work. Their work must embrace the methodical supervision of it, and there was generally plenty for them to do in that respect. Mr. Tucker thought Baron Jüptner approached the transcendental in wishing for greater accuracy than had been obtained in the phosphorus determinations made by the American Commission. Those results apparently left nothing to be desired in respect of the present requirements of steel analysis.

Probably one of the most serious sources of error in the practice of ironworks laboratories, and indeed in the practice of private laboratories, was due to the assumed accuracy in the weights supplied by balance-makers. Mr. Tucker had found very serious differences in the weights supplied by makers of high repute, and it would be well if analysts either required a warranty with the standard weights, and such warranties were now often given, or that they should send their weights to Kew or elsewhere to be standardised. The ordinary weights in use could then be periodically adjusted from the standard set.

In conclusion, Mr. Tucker thanked Baron Jüptner for the splendid monograph he had given the Institute on ironworks laboratory practice, and though much of the information appeared to be impracticable in everyday practice, there was an ideal, the setting up of which could not fail to be of signal service to the proceedings of the Institute.

The following paper was then read :—

ON THE

RATE OF DIFFUSION OF CARBON IN IRON.

By Professor W. C. ROBERTS-AUSTEN, C.B., F.R.S. (Member of Council).

THIS communication is a somewhat slender one, and is mainly
intended to direct attention to a subject which has been too
long neglected, although experiments directly connected with it
have from time to time been submitted to this Institute.   The
conversion of iron into steel by the passage of *solid* carbon to
the centre of a *solid* mass of iron is one of the oldest facts
recorded in scientific literature.   The name "cementation" had
been given to it from its analogy to another process of great
antiquity, the removal of silver from *solid* gold plates by the
action of a cement, a process which was accurately described by
Geber in the eighth century, and was used by the Chinese,
centuries before our era.   Scientific interest in the process may
be said to date from the time of Bergman, who in 1781 pointed
to the carburisation of iron as the cause of its conversion into
steel.   As regards the cementation of iron by carbon, which
constitutes the old method of steel making, Le Play in 1846
considered it to be "an unexplained and mysterious process,"
and he attributed the transmission of carbon to the centre of the
iron solely to the action of carbonic oxide.   Gay Lussac con-
fessed that a study of the process "shook his faith in the belief
generally attributed to the ancient chemists that *corpora non
agunt nisi soluta*, . . . for it is certain," he adds, "that all
bodies, solid, liquid, or aëriform, act upon each other; but of the
three states of bodies the solid state is the least favourable
to the exercise of chemical affinity."   This statement of Gay
Lussac's clearly points to the existence of fluid molecules in a
mass, which is, as a whole, solid, and it also leads to the belief
that solids may diffuse in each other.   I have already traced
the history of the diffusion of solids in the Bakerian lecture
delivered in February last before the Royal Society.   In it I
refer to some experiments of my own which show that *solid* gold

or *solid* platinum will diffuse into solid lead even at the ordinary temperature, while the rate of diffusion becomes singularly rapid if the temperature of the lead be raised to 150°.

The process of cementation has been exhaustively studied by Mannesmann,* but as regards, however, the diffusion of carbon, in 1881 M. A. Colson communicated a paper to the *Académie des Sciences*, in which he attempted to measure the diffusion rate of carbon in iron, and showed that when iron is heated in carbon there is a mutual interpenetration of carbon and iron at so low a temperature as 250°. This work, it should be mentioned, was led up to by that of Marsden, Violle, and other experimenters, some of whom demonstrated that solid carbon will permeate strongly heated porcelain.

I may add that any lingering doubt as to whether gas need necessarily intervene in the cementation of iron was removed in 1889 by an experiment of my own, by which I endeavoured to complete the series of experiments on the carburisation of .ron by the diamond which, beginning with Clouet's work in 1798, was continued by a host of experimenters down to Margueritte, 1865; Hempel, 1865; and Osmond quite recently. In my own experiment, pure electro-iron was carburised *in vacuo* at a temperature far below the melting-point of iron, and under conditions which absolutely preclude the presence or influence of occluded gas. Osmond has shown (and some photographs illustrating the fact were exhibited) that when pure iron is carburised by the diamond, the iron is gradually penetrated by the carbon; and the question arises, at what rate does this penetration take place? There is not as yet much data which can be quoted in answer to this question; but the diagram (Plate V.) represents the carburisation of a steel rail already containing 0·26 per cent. of carbon, by the additional amount of carbon imparted to the metal during the course of the Harvey process. The time during which carburisation is effected is about 120 hours in the case of an armour plate. The co-ordinates of the curve are respectively, *distance* to which the iron is penetrated by the carbon, and the *amount* of carbon which has so penetrated.

* *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1879, vol. lviii. p. 31.

Now, if this curve be compared with one which represents the diffusion of common salt in water, or the diffusion of gold or platinum in solid lead, it will be found that the curve for the carburisation of iron resembles a true diffusion curve.

It would appear, therefore, to be very desirable, now that our whole scheme of naval defence depends so much on the carburisation of steel by the Harvey process, to work out the theory of carburisation which appears to present a simple case of the diffusion of solids.

DISCUSSION.

Mr. G. J. SNELUS, Vice-President, had been exceedingly interested in the remarks of Professor Roberts-Austen, as personally he took a very great interest in the question. He did not know whether any of the members would remember that in the earlier days of the discussion about carbon in iron he had shown that he had long looked upon it as a question of solution somewhat similar to what Professor Roberts-Austen had described just now, namely, that it was comparable to the solution of a salt in ordinary water. It had also occurred to him on more than one occasion to find how rapidly these solutions and separations and segregations took place. He thought that he had on a previous occasion mentioned one which was most remarkable. He was dealing with an alloy of zinc and iron, and he wanted to prevent segregation. He thought that if he cast this alloy of zinc and iron into an iron mould and chilled it suddenly, he should be doing the best in his power to prevent segregation, but to his utter astonishment he found that even under those circumstances segregation took place almost instantaneously, and that from this zinc alloy the core contained not much more than half the amount of iron that the circular ring outside contained presumably in the crucible, although the metal was quite homogeneous, but at the moment of solidification there was a sudden separation of the two elements. This, although not exactly what Professor Roberts-Austen had been alluding to, had a bearing upon the subject. They were very much indebted to Professor Roberts-Austen for bringing before them these facts, and he was sure that they would well repay most careful attention on the part of the younger chemists who had time and energy to devote to them. He was sure that Professor Roberts-Austen had led the way to something which would turn out to be of very great service to the Institute if it was well followed up.

Mr. J. E. STEAD, Member of Council, might add a little experiment to those of Professor Roberts-Austen in working on the cementation process—the minus cementation process, if he might

so describe it, to distinguish it from the ordinary cementation process in which carbon was added to the metal. He referred to the taking out of the carbon, by oxidising influences from the outside; when that was effected, and the curve plotted out in the same way as shown in Professor Roberts-Austen's diagrams, the curve was very similar to that drawn by Professor Roberts-Austen, but it was of course reversed, the only difference being that towards the outside of the piece there was a neutral area where there was no variation in carbon, which was practically absent.

The CHAIRMAN then proposed a vote of thanks to Professor Roberts-Austen for his very interesting address.

Professor W. C. ROBERTS-AUSTEN, C.B., Member of Council, in acknowledging the compliment, asked, in continuation of the observation made by Mr. Snelus, whether it was not usual to allow us to accept the fact that galvanising iron greatly diminished the strength of a chain, and that whether a chain with a galvanised coat was not weaker than one without. That might be due partly to the destruction of the surface tension of the material —a very important thing—but it was also due, he thought, to the rapid diffusion of the zinc into the iron.

The following paper was then read :—

MOND PRODUCER GAS APPLIED TO THE MANUFACTURE OF STEEL.

By JOHN H. DARBY, Brymbo.

IN 1889 Dr. Ludwig Mond brought his process for the manu-
facture of producer gas with recovery of sulphate of ammonia
before the public in a presidential address to the Society of
Chemical Industry.   It will therefore not be necessary for me
to describe the process and apparatus employed in any great
detail.   I will confine myself as much as possible to dealing
with the improvements that have been made since that date, and
with the application of the gas to the manufacture of steel.

I notice in a paper read before the West of Scotland Iron and
Steel Institute in April 1893 by Mr. George Ritchie, the following
remarks in reference to the Mond producer:—" The ideas em-
bodied in this arrangement could only have come from the brain
of the inventor's genius, but (as he himself remarks) the cost of
the plant is considerable, and in the author's opinion we must
look again for a solution of this most interesting problem."   I
hope to be able to show that Mr. Ritchie is mistaken, and
that in its present form the Mond producer presents the most
economical and efficient method of making producer gas for
industrial purposes.

When fuel is gasified in the ordinary producer, the products
of distillation, including tar, first leave the fuel, and the fixed
carbon is ultimately converted into carbonic oxide.   This raises
the temperature of the contents of the producer and the resulting
gas to a high degree, and is sufficient to decompose most of the
ammonia originally contained in the fuel as nitrogen, as well as
to effect the distillation of the volatile products.   The initial
heat in the resulting gas is to a great extent lost, and perhaps
its only useful office is to keep the tar from depositing before the
gas arrives at the point of consumption.

It is evident that at whatever temperature gas enters the
regenerator, the waste gases will, when the furnace is reversed,
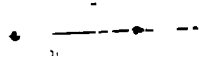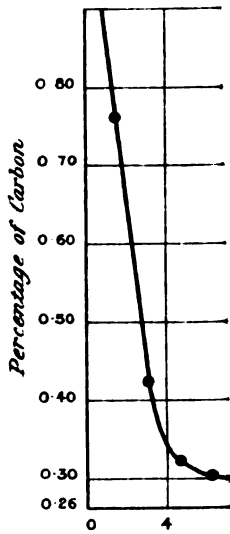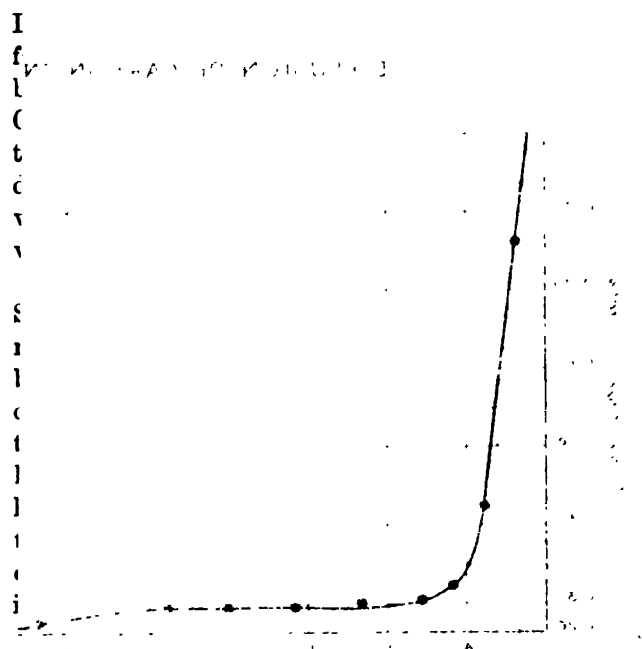
leave that regenerator at a temperature not less than that of the ingoing gas. The sensible initial heat in the gas is therefore not utilised in the furnace, but escapes up the chimney-stack without doing useful work. I should, however, remark, that a small portion of the heat spoken of is commonly employed in decomposing steam in steam-jet blown producers.

The objects Dr. Mond wished to obtain in his producer plant were to utilise the heat developed by the combustion of carbon to carbonic oxide, by transferring the sensible heat in the steam and gas, leaving the producer to the air and steam entering the producer. In this way he was enabled to use far more steam than is generally employed, and to work with a low temperature in the producer, preventing the decomposition of the ammonia. This enabled him to obtain the enormous yield of nearly 100 lbs. of sulphate per ton of fuel, at the same time producing a much larger volume of gas of about the same calorific value, vol. for vol., compared with ordinary producer gas.

The recovery of by-products from producer gases has been the subject of much consideration, but, as far as I am aware, satisfactory results have not been obtained in using washed gases in the regenerative steel furnace. I understand that a steel furnace was erected by the Coltness Iron Company, which worked well with ordinary Scotch blast-furnace gas (see analysis) before this gas was washed to recover the ammonia, &c. Subsequently apparatus was erected for the recovery of ammonia, but the steel furnace did not work satisfactorily with the washed gas, and it is at present being worked by producer gas made in the ordinary way. Cooling the blast-furnace gas causes tarry vapours to be condensed, and the gas is impoverished thereby. This is possibly the reason why the furnace in question ceased to work satisfactorily with the washed gas.

Scotch Blast-Furnace Gas (using Coal). (RITCHIE.)

	Unwashed Average of Two Analyses by Volume per Cent.		Washed Average of Two Analyses by Volume per Cent.
Carbonic anhydride	6·80	...	6·30
Carbonic oxide	27·70	...	27·70
Methane	2·69	...	2·72
Hydrogen	6·81	...	7·55
Nitrogen	56·00	...	55·73
	100·00	...	100·00
Comparative calorific value	1274	...	1299

It is probable that the analyses of the unwashed gases do not show the value of the tarry vapours, as they would be condensed in the apparatus, and therefore not taken into account in either case.

In a furnace under my own observation, working with gas supplied from a Wilson's gas-producer, the following is the difference in comparative calorific value of the gas before it entered the regenerator and after it left the regenerator :—

Gas before Regenerator, probably without Tarry Vapours.

	Average of Five Analyses. Analysis by Volume per Cent.
Carbonic anhydride	7·63
Carbonic oxide	21·73
Ethylene	1·06
Methane	3·05
Hydrogen	12·60
Nitrogen	53·80
	99·87

Comparative calorific value, 1487.

Same Gas after Heating in Regenerator, including Tarry Vapours.

	Average of Five Analyses. Analysis by Volume per Cent.
Carbonic anhydride	5·19
Carbonic oxide	24·79
Ethylene	0·41
Methane	1·33
Hydrogen	19·17
Nitrogen	48·98
	99·87

Comparative calorific value, 1524.

In the first instance the calorific value has been determined without the tarry vapours, which were condensed in the collecting tubes of the apparatus employed, and in the second instance it included the tarry vapours, as they were permanently fixed, and their products decomposed in the passage through the heated regenerator. This shows, together with the increase in volume, what probably is the heat value of tarry vapours in the producer gases.

Dr. Mond found that the amount of nitrogen contained in different fuels which he experimented on varied between 1·2 and

1·6 per cent. When he introduced, together with the super-
heated air required to burn the fuel in the producer, 2½ tons of
steam for every ton of fuel consumed, he found that over 70
per cent. of the total nitrogen in the coal could be recovered, in
the form of sulphate of ammonia, from the producer gases, this
amounting in practice to nearly 100 lbs. of sulphate of ammonia
per ton of fuel. Only about one-third of the steam introduced
into the producer is decomposed in its passage through the fuel,
so that two-thirds remain in the gases, leaving the producer at a
temperature of 450° to 500° C. The problem was to return this
steam or its equivalent to the producer, and to transfer the
initial heat in the gas and steam leaving to the air and steam
entering the producer for the combustion of the fuel. The
difficulties in the way of attaining this end, and at the same
time recovering the small amount of ammonia in the immense
volume of gas to be dealt with, are very great.

The gas leaving the producer from 1 ton of coal is about
160,000 cubic feet, equal to 4530 cubic metres at 15° C. and
atmospheric pressure. Mixed with this gas is 100,000 cubic
feet, equal to 2831 cubic metres of steam. Under the circum-
stances the application of cooling arrangements such as are used
in connection with the Scotch blast-furnace is out of the ques-
tion. Dr. Mond solved the problem in the following way :—

The hot producer gas is passed through a series of pipes
surrounded by an annular space, through which the mixture of
air and steam to be introduced into the producer is led in an
opposite direction, thus taking up the heat from the hot gas and
becoming superheated. Thence the producer gas is led through
a rectangular chamber partly filled with water, which is thrown
up in a fine spray by revolving beaters so as to fill the whole
area of the chamber. This water, of course, becomes hot, a
certain quantity of it evaporates, and the spray produced washes
all dust and soot out of the gases. From this chamber the gas,
which is now cooled down to about 100° C., and is loaded
with a large amount of water vapour, is passed through a leaden
scrubber filled with perforated bricks, in which the ammonia con-
tained in the gases is absorbed by dilute sulphuric acid. In this
scrubber a fairly concentrated solution of sulphate of ammonia,
containing 36 to 38 per cent., is used, to which a small quantity

of sulphuric acid is added, so that the liquid leaving the scrubber contains only 2·5 per cent. of free acid. This liquid passes through a separator in which it is clarified. The greater portion of the clear liquid is, after the addition of a fresh quantity of acid, pumped back to the scrubber. The remaining portion of the liquid is withdrawn, and is evaporated in conical lead-lined pans furnished with lead steam coils, which are kept constantly filled by the addition of fresh liquor until the whole mass is thick. This is then run out on a strainer, and yields, after draining, a sulphate of ammonia of very fair quality, and up to the market strength of 24 per cent. of ammonia, which finds a ready sale. The mother liquor, which contains all the free acid, is pumped back to the scrubber. The gas on entering the scrubber contains only 0·13 vol. per cent. of ammonia, and on leaving the scrubber it contains less than one-tenth of this quantity. Its temperature has been reduced to 80° C., and as it is not fully saturated with moisture at that temperature, no condensation of water takes place in the scrubber.

The gas next passes through a second scrubber constructed of wrought iron and filled with perforated wood blocks. In this it meets with a current of cold water which condenses the water vapour, the water being thereby heated to about 78° C. In this scrubber the gas is cooled down to about 50° C., and passes from it to the gas main leading to the various places where it is to be consumed.

The hot water obtained in this second scrubber is pumped through a third scrubber, also of wrought iron, through which, in an opposite direction to the hot water, cold air is forced. The air is forced by means of a blower through the scrubber, and thence into the producer. The air thus gets heated to about 74° C., and becomes saturated with moisture at that temperature by its contact with the hot water, while the water leaves this third scrubber cold enough to be pumped back through the second scrubber. The same water is thus constantly used for condensing the water vapour in one scrubber and giving it up to the air in the other. In this way about one-half of the steam required for the producer is recovered and returned to the producer. The rest of the steam required is in part obtained as exhaust steam from the engines driving the blowers and pumps

required for working the plant, and the remainder wherever possible from any other exhaust steam available.

The gas-producers used, which are a very important feature of the plant, are cylindrical in shape, tapering at the bottom. They are 10 feet in diameter inside in the cylindrical part, and about 21 feet high. Towards the bottom of the producer-casing the sides taper inwards, and end in a conical grate having a round opening in the centre, through which the ashes from the burnt fuel descend into the water lute, whence they are easily removed. The upper portion of the producer is provided with a cone and hopper for introducing the fuel, and underneath the cone a bell-shaped casting is placed about 7 feet long, which is kept partially filled with fuel. The casing of the producer consists of two wrought-iron shells, having an annular space between them ; and the air, saturated with steam, which is blown in, circulates round the producer between the two casings. In this way it is super-heated and evenly distributed, and eventually finds its way through the conical grate spoken of. As the air is thus evenly distributed over the whole area where it is required, the fuel in the producer is consumed regularly, and does not, therefore, burn into holes.

The producer is kept filled up to the bottom of the bell-shaped casting spoken of. When fuel is introduced, it is first of all distilled, as in an ordinary gas retort, inside the bell-shaped casting. The gases given off have to force their way downwards and through the hot fuel at the point where it leaves the bell and joins the main body of the producer. The tarry vapours in their way through the hot fuel become fixed, and little or no trouble is found with the tar in subsequent operations. The gas is taken off from the producer by a pipe in the usual way, and passes up and down a series of wrought iron tubes on its way to the mechanical washer. These tubes are surrounded by annular casings, the outside of which is protected from the air by some non-conducting material. On removing the plugs at the bottom of these tubes, nothing but dust issues with the gas, showing absence of tar. I am quite aware that in other producers attempts have been made to permanently gasify the tarry vapours, and in the Wilson producer an annular chamber is provided in the brickwork surrounding the freshest portions of fuel. The

object desired, however, in the last producer named is not attained. It will thus be seen that the Mond gas, although washed, is not impoverished by the removal of the tarry products, but that they go forward as permanent gas. The steam saturated air coming forward to the producer passes through the annular casings referred to, is heated in them at the expense of the initial heat in the gas itself, and in this way returns a considerable part of the heat in the gas to the producer.

The labour in connection with this producer is very low. Repairs, owing to the low temperature at which it works, are nominal. The lining in a producer which has been working for two years is now almost as good as when it was first put in. There is no clinkering, as the temperature is never sufficient to make a clinker; only rotten ash is to be found, which is almost free from carbon. There is no difficulty in stopping the plant at week-ends and re-starting.

The quantity of fuel gasified per producer per twenty-four hours is twenty to twenty-two tons.

The details of construction of this plant will be easily understood by reference to Plate VI.

The gas obtained in a dry state on an average contains—

	Per Cent. by Volume.
Carbonic anhydride	17·1
Carbonic oxide	11·0
Olefines	0·4
Methane	1·8
Hydrogen	27·2
Nitrogen	42·5
	100·00

Total combustible gas 40·4, giving about 1350 K. C. Cals. as determined by a calorimeter, per m³.

The calorific value of this gas, per unit of weight of fuel gasified, is higher than that of ordinary producer gas, and is equal to 80 per cent. of the calorific value of the fuel used. Producer gases, as a rule, do not, I am informed, carry forward more than 60 to 65 per cent. of the calorific value of the fuel.

As before stated, nearly 100 lbs. of sulphate of ammonia are obtained from every ton of fuel, or one ton from every twenty-three tons of fuel.

The producer plant may be worked in two ways, either with

recovery of sulphate of ammonia or without. In the latter case the plant is very much simplified, as the lead tower and sulphate plant generally are not required; on the other hand, the large revenue from the sulphate is of course not obtained. If the plant is worked without recovery of sulphate of ammonia, the advantages to be derived over ordinary producers are, in the first place, a greater efficiency—20 to 25 per cent. of the original fuel being saved in accomplishing the same amount of work; secondly, production of clean washed gas that will carry any distance without deposit; thirdly, a reduction of the percentage of sulphur contained in the gas; fourthly, a substantial saving of labour at the producer and low cost of repairs; and there are also many other minor advantages with this producer, which in the aggregate become an important factor.

The cost of producing sulphate of ammonia, including labour, stores, and fuel for raising the steam required for pumps, blowers, &c., but assuming that there is sufficient waste steam available to make up what is additionally wanted at the producer, and taking credit for the cost of steam used in a Wilson producer and the saving in wages compared with same, comes to £3, 6s. 7d. per ton, taken from actual working. This at the present abnormally low price of sulphate leaves a substantial margin.

Mr. Charles F. Jenkin has recently pointed out in his very interesting paper on the efficiencies of gas-producers,[*] how harmful steam is when it is carried forward in hot gas. I have shown that the steam is not by any means entirely decomposed in the producer, and if the Mond gas went forward to the steel furnace in the condition it is made, it could not, as a matter of fact, be used. I have described how Dr. Mond gets rid of the large quantity of heated steam the gas contains, and how he returns it to the producer, thus providing a continuous supply of the necessary steam. The gas is delivered for use at the ordinary temperature saturated with vapour at that temperature. For instance, at a temperature of 50° C., the gas only contains 111 grams of water vapour per metre of dry gas, and working with gas containing this amount of moisture, there is no apparent drawback in the steel furnace.

[*] *Minutes of Proceedings of the Institution of Civil Engineers*, 1896, vol. cxxiii. pp. 328-351.

Owing to the general belief that washed gas was not satis-factory in the manufacture of steel, Dr. Mond, by my advice, determined to put down a small steel furnace to demonstrate whether his gas would work satisfactorily and give the high temperatures required quickly and efficiently.   During the latter portion of 1895 a regenerative furnace was erected at the Win-nington works of Messrs. Brunner, Mond & Co.   It was a three-ton furnace, and measured 12 feet between the blocks.

The best performance was a complete charge in 7 hrs. 35 min., thus working rather faster than three charges per day of twenty-four hours.   No hitch of any kind occurred in working this furnace, nor did any trouble develop itself with the washed gas.

The steel made contained from 0·14 to 0·45 per cent. of carbon, 50 per cent. containing under 0·2 per cent. of carbon.

The average complete analysis of nine casts gave the following results :—

		Per Cent.
Carbon	. . . .	0·240
Silicon .	. . . .	0·038
Sulphur	. . . .	0·039
Phosphorus	. . . .	0·037
Manganese .	. . . .	0·457

The mechanical test of twelve samples of the steel containing from 0·16 to 0·22 per cent. of carbon gave the following results :—

Cast No.	Carbon, per Cent.	Diameter, Inches.	Breaking Strain per Sq. In. Tons.	Elongation in 8 Ins., per Cent.	Percentage of Contrac-tion of Area.	Limit of Elasticity per Sq. In. Tons.
20/1	0·17	1·14	25·6	35	50	16·4
2	...	,,	25·5	32	51	16·4
25/1	0·22	,,	25·8	35	53	16·6
2	...	,,	27·6	32	53	17·0
30/1	0·16	,,	25·8	36	53	16·4
2	...	,,	25·8	33	53	15·9
35/1	0·16	,,	25·4	33	56	16·7
2	...	,,	25·2	35	56	16·1
40/1	0·18	,,	27·3	32·5	53	17·6
2	...	,,	27·1	33	53	17·3
41/1	0·17	,,	26·2	35	53	17·1
2	...	,,	26·3	34	51	17·4

There were no skulls in the ladle from the beginning to the end of the experiment, the metal always being hot and settling quietly in the moulds.

During the experiment forty-one charges were converted into

steel. Average time: charging, 0 hrs. 18 min.; melting, 3 hrs. 9 min.; working, 5 hrs. 39 min. Average duration of charge, 9 hrs. 6 min. Shortest time taken, including charging and repairs, 7 hrs. 35 min. Total make of steel, 99 ton 3 cwt. Yield on the metals charged, 95·33 per cent.

Description.	Weight of Materials Charged.				Used per Ton of Steel.
	Tons.	Cwt.	Qrs.	Lbs.	Cwt.
Hæmatite pig iron	79	10	3	0	16·04
Steel scrap	23	12	3	0	Lbs. 4·77
Ferro-manganese	0	16	2	2	18·7
Iron ore	16	10	0	0	Cwt. 3·39

The measurements as to the quantity of gas used have been given me, but as the furnace was drawing its supply from the works mains, it is difficult to arrive at this accurately. I would prefer to let the question of consumption rest by saying that three charges of steel were made in twenty-four hours, and that the amount of gas consumed by the furnace was not appreciable at the gas-producer.

One of the points of difference I observed between the Mond gas in the steel furnace and ordinary producer gas was the considerable length of the flame. In a shorter furnace than the one referred to sufficient gas could not be kept on without reaching right across from port to port. With the furnace of the size given the gas seemed to thoroughly expend itself, and kept the steel at a satisfactory temperature during the whole operation with apparently a very small consumption of gas. The bath boiled all over equally, and as an indication of the equal temperature in the furnace, I would mention the fact that the circulation of the slag floating on the metal, which in my experience is generally towards the incoming gas, in this case ceased altogether, or, if there was any circulation, it was in the same direction as the gas in the furnace.

The experiments show conclusively that gas of the composition given is entirely satisfactory for the manufacture of the softest kinds of steel, and that it does not contaminate the metal with sulphur.

In the following table, No. 1 is the analysis of the Mond gas, taken before it entered the regenerative chambers ; No. 2 is the analysis of the same gas after it had passed the regenerator and been heated.   The comparative calorific value is given in each case.   Average analyses of ordinary Wilson producer gas, which is being employed continually for the manufacture of steel before entering the regenerator, and of the same gas after it has passed the regenerator and been heated, have been given before.   The great difference in composition will be noted.   In the Mond gas there is a great fall in the percentage of hydrogen and a rise in the carbonic oxide, while the carbonic acid has been materially reduced.   In the ordinary producer gas the reverse takes place as far as the hydrogen is concerned, the carbonic oxide is increased, while the marsh gas and carbonic acid are diminished. It seems probable in the case of the ordinary producer gas that the hydrogen is partly increased at the expense of the decomposition of the marsh gas and olefines, and that the carbonic oxide is increased by the decomposition of part of the carbonic acid by liberated carbon from the decomposed hydrocarbons.   The results I have placed before you are the average of those obtained by two separate chemists.   Both agree within the limit of experimental error.

The alteration in producer gases on heating is a question that requires further consideration.   It would seem as though there is a tendency to form one composition at which producer gases most easily maintain themselves when highly heated, the composition of the Mond gas after heating and the Wilson gas after heating being somewhat similar.

	Mond Gas.		Wilson Gas.	
	No. 1. Before Regenerator.	No. 2. After Regenerator.	No. 1. Before Regenerator.	No. 2. After Regenerator.
Carbonic anhydride . .	17·8	10·5	7·63	5·19
Carbonic oxide . . .	10·5	21·6	21·73	24·79
Ethylene	0·7	0·4	1·06	·41
Methane	2·6	2·0	3·05	1·33
Hydrogen . . .	24·8	17·7	12·60	19·17
Nitrogen	43·6	47·8	53·80	48·98
	100·0	100·0	99·87	99·87
Calorific value . . .	1430	1444	1487	1524

It has been frequently stated, and I believe the late Sir William Siemens held the opinion, that non-luminous gas would not work satisfactorily in the steel furnace. Before heating, the Mond gas burns with a non-luminous flame. In the steel furnace, however, the men found no difficulty in working with the gas, and it seemed in practice when highly heated to burn with a brilliant white flame. Possibly the change in composition in the regenerators which has been spoken of may have something to do with this, as in every case examined the gas contained finely divided carbon, which was deposited on the walls of the apparatus. To show, however, that a steel furnace will work satisfactorily with what is generally known as non-luminous gas, I would instance the furnace at the Trimsaran Works in South Wales. Here the gas, I am informed, is made from anthracite coal, and is certainly before heating a non-luminous gas. I may say in conclusion, that the comparative calorific values in this paper have all been calculated; they are in the terms of kilogramme-centigrade calories; they are therefore not absolute, but comparative. Great care was exercised in making the various analyses given, and they are in almost all cases the average of a large number made.

Analyses by Volume of various Producer Gases at 15° C.

	Mond Gas.		Brymbo.	Dowlais.	Bolckow, Vaughan & Co.'s
	Own.	Brunner, Mond & Co.'s	Average of Five own.	By Dowlais Co.	By Bolckow, Vaughan & Co.
Carbonic anhydride .	17·8	17·1	7·63	7·00	7·00
Carbonic oxide . .	10·5	11·0	21·73	22·00	31·00
Ethylene . . .	0·7	0·4	1·06	...	...
Methane . . .	2·6	1·8	3·05	1·00	1·50
Hydrogen . . .	24·8	27·2	12·60	9·00	10·00
Nitrogen . . .	43·6	42·5	53·80	61·00	60·00
	100·0	100·0	99·87	100·00	99·50
Comparative caloric value . . . }	1430	1400	1487	1034	1081

	Scotch Blast-Furnace Gas.	Steel Co. of Scotland.	Siemens Closed Steam Blown.	Wilson Gas.
	Sir Lowthian Bell.	By Steel Co. of Scotland.	By Ritchie.	By Pattison & Stead.
Carbonic anhydride .	8·61	8·00	5·2	5·25
Carbonic oxide . .	28·06	22·00	24·4	23·66
Ethylene .	...	...	...	...
Methane . . .	4·37	4·00	2·4	3·05
Hydrogen . . .	5·45	15·00	8·6	10·55
Nitrogen . . .	53·38	51·00	59·4	57·55
	99·87	100·00	100·0	100·06
Comparative caloric value . . . }	1423	1500	1225	1324

DISCUSSION.

Professor H. BAUERMAN said that he had read the paper with very great interest. A very important point was the particular one to which Mr. Darby called attention at the end of his paper, namely, the reversal of the composition. These analyses of the gas before and after the regenerator showed that there was a very considerable apparent alteration in the composition. It was not quite apparent from the figures what it was, so that he had taken occasion to work them out into weight. From these figures it appeared that the change which actually took place was that, with these gases in the regenerator, they obtained the inverse reaction of water gas, that was to say, carbonic anhydride was partly reduced by hydrogen, water and carbonic oxide being produced. According to the figures, it would seem that about one-third of the carbonic acid was decomposed, and that would just account for the hydrogen that was missing when it was worked into weight. That was a reaction in gas chemistry which, he thought, one did not generally recognise. It seemed in this particular case, where they had so much carbonic acid in the presence of so much hydrogen, that actually the hot bricks there would, so to say, work against the producer, that was, a low water gas in the producer had its carbonic oxide brought up by the inverse action before it went into the furnace. It did not really take much heat; it would only take about 3000 units per unit of weight to do it, and that, of course, could very easily be supplied by regenerators at a temperature probably of about 1200° C.

Mr. G. J. SNELUS, Vice-President, said that by the invitation of Mr. Darby he had been to see the Mond gas producer, and had carefully examined its working as far as it could be seen from merely going over the plant. The whole thing struck him as being remarkably well worked out. To begin with the producer, he never saw such clean ash coming away from a producer in any part of the world. It was perfectly clear that, if they were going to get the greatest economy out of their fuel, the ash

must come away without any residual carbon in it, and he had
noticed that the ash which was taken out from the bottom of
the producer was almost free from carbon.   It was of a light
grey in colour, and it was also very easily removed—which was
a point of very great importance.   There were not the slightest
signs of clinker in it, and the producer worked with the greatest
ease.   There were many noteworthy points about the producer.
Labour was reduced to a minimum.

The mode of charging the producer was very ingenious.
There was no handling of the coal by the workman; it was
put into a travelling carriage over the top of the producer,
brought over the opening, and then a short length of tube put in
between, and the coal was dropped into the intermediate recep-
tacle with the least possible trouble; it was kept in the inter-
mediate receptacle, and there formed, of course, a seal to the gas.
There was a double valve, and when the lower valve was opened,
of course the coal was dropped into the producer.   There was no
escape of gas from the top of the producer when this operation
took place, a point, he need not say, of very great importance, as
saving all waste, and also because it was very much cleaner and
nicer for the men who happened to be working about it.   They
all knew the immense volume of gas which came off a producer
when a charge of coal was dropped in in the ordinary way.
Then again, there was the ingenious way in which the tarry
matter was decomposed, by carrying the charging apparatus well
down into the producers, so that the products of the decomposi-
tion of the coal, instead of coming straight off through the cool
mass of the material, were caused to pass under the red-hot fuel,
and in this way the tar was certainly thoroughly decomposed.
It was only necessary to open a small hole on the side of the
producer, above the red-hot fuel, and another adjoining it, so that
the gas could come out above the raw fuel, to see the immense
difference in the two kinds of gas; one was a perfectly clean,
clear gas, the other was that thoroughly smoky, tarry one which
they saw generally.   He was very much struck with the success
of this part of the operation.

Then again, there were many little contrivances about it which
showed remarkable ingenuity.   For instance—this was a very
small matter—the poking holes, instead of being covered in the

usual way, with a plug, were just covered with a cannon ball, so to speak, which was rolled on its course, and formed a very efficient closing apparatus. That was a trifling matter, but it showed the amount of ingenuity which had been brought to bear on the whole thing. Then again, the bars of the regenerator were made in a quite different way to those ordinarily employed. They were large bars of iron—he thought about 2 in. and $2\frac{1}{2}$ in. square, in section, but they were simply hung upon a bar around the furnace, so that they could be moved asunder, if the men wanted to get at the fire to loosen the fuel, and they were very easily replaced. From the very nature of the way in which the producer was worked, they did not seem to burn out at all. The mode of removing the ash was not an uncommon one. He could not ascertain for himself what was the production of ammonia. There was no doubt at all that the figures given in the paper were correct, and that the enormous amount of 100 lbs. of sulphate of ammonia from a ton of coal was obtained. That, of course, was the crux of the whole thing, because, even at the present low price of sulphate of ammonia, it was perfectly clear that they were getting as much in value from the sulphate as the whole of the coal which they used cost. That was a most important factor in the whole thing.

He thought the question, which he was asked to go and see and report upon, was rather whether that gas could be used for steel-making purposes, and he must say that the small furnace, which was working there, was working in an admirable manner. The heat was thoroughly good, and the gas was clear. He saw the steel cast. As Mr. Darby had said, it ran beautifully, solidly, into the moulds, and there did not seem to be the slightest difficulty at all in keeping sufficient heat, even with this very small three-ton furnace. They all knew that the difficulty of working a small Siemens furnace of this character was very great, and he thought that it was very strong proof of the success of the gas for the purpose, that they could work this very small furnace in a continuous way and without any trouble. There was no skull, as Mr. Darby had said, in the ladles, the steel was thoroughly fluid, and in every way it seemed to him to be a great success. There was this point about the whole thing, however, that the apparatus was very costly ; but, if it would produce a profit,

there was capital enough in our large ironworks to find money to put it up. It certainly was not an apparatus which a small firm could venture to go into and use, but if it would produce a profit when employed on a large scale, he was quite sure that it would be well worth the managers of our large iron and steel works looking into the question most carefully. As far as he could see, there seemed to be every probability that it was a thoroughly successful process.

Mr. JAMES RILEY, Vice-President, was sure the members were greatly indebted to Mr. Darby for the excellent and interesting paper he had read, and to Dr. Mond for permitting these particulars to be made known. Dr. Mond had rendered very great service to them all, and he was quite sure they would all appreciate it. For many years the desire to recover the ammonia formed in the producer had been a very strong temptation to most of them. In the early days of the Siemens producer the inducements to recover the ammonia were not very strong and the prospect of success was not very great, for the quantity of ammonia present in those original producers was not more than equal to 4 or 5 lbs. of sulphate to the ton of coal gasified ; hence there was nothing to encourage one to seek to recover that ammonia. Subsequently, a few years ago, when the steam-blown producer came more into use the quantity of sulphate of ammonia to the ton of fuel charged had risen to from 17 lbs. to 21 lbs. That quantity made it rather more tempting, but the fact was constantly before them of the costly nature of the plant that would be required, and although some of their friends might perhaps not quite realise the strength of the doubt they had of the value of the fuel after it had been so heated, yet it was a very strong doubt.

The work of Dr. Mond had been rewarded with success in the effort to obtain large quantities of ammonia. He was an ammonia maker, and therefore it might be said that he had been very successful in the object he had before him—that of making ammonia. When, therefore, Mr. Darby spoke to him (Mr. Riley) about that process for the recovery, he had replied, "Well, we all of us have some doubt, by reason of past discussions and past experiments, as to what is the value of the gas for steel-making

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purposes ; we are steel and iron makers first, and ammonia recoverers secondly." Now there did not seem to be any possibility of determining that point, except by the way which Dr. Mond had taken with very great enterprise, and in a manner which should be extremely useful to all of them.

When discussing the matter with Mr. Darby, he had ventured to suggest that a great service would be performed if a small steel furnace were built so as to settle that doubt at once. That had been done; the furnace had been built. He had not himself been able to see it at work, although Mr. Darby had been kind enough to ask him to do so, but a representative had gone there, and the report made by him showed that the steel was worked in a most satisfactory way, and that the results, so far as could be seen, were everything that could be desired. It would therefore seem that that one doubt had been to a very large extent removed, that it would be possible to recover the ammonia, and to use the gas, after being freed from ammonia, for their ordinary purposes.

The next obstacle was that which their friend Mr. Snelus estimated so lightly, but which was not quite so lightly held by some of them, the great cost of the installation if it was to be carried out on any scale commensurate with the quantities of fuel which were in use in large works. Doubtless that also could be faced if, as Dr. Mond had said to him on the previous day, there was a prospect of a return of 25 per cent. upon the outlay.

Mr. F. W. PAUL said that, like many others, he had the pleasure of visiting and seeing the small furnace at work at Winnington by the invitation of Mr. Darby, and he would take this opportunity of thanking that gentleman for the very thorough way in which every detail was shown and explained, and as much information given as it was possible to gather during a visit of a day or half a day's duration. The composition of the steel as given by Mr. Darby, judging from the one charge that he saw worked, fully bore out what Mr. Darby had said ; the same was the case with regard to the working of the furnace ; in short, he might say he saw no practical reasons why this gas should not be used for the manufacture of steel. The important change which took place in the composition of the gas in its transit through the chambers was one point which had exercised his mind for a very

1896.—i.   L

considerable time, and he was very glad to see that his views had been fully confirmed by the analyses which Mr. Darby had given in the paper, some of which, however, were slightly at variance. Those analyses showed that the question of the composition of producer-gas was one that was worthy of very much more consideration than had hitherto been given to it. In his investigations he had found, as an invariable rule, that the marsh gas was all decomposed in transit through the chambers. This he found was at variance with Mr. Darby's results, and likewise with the researches given in an exhaustive paper by Mr. H. H. Campbell to the American Institute of Mining Engineers.[*] Probably the reasons for this variance might, in a measure, be due to a difference in the composition of the initial gases, the size of the chambers, the intensity of heat in the chambers, and other local differences. In a number of analyses of those gases which were taken before and after passing through the chambers, he found that there were so many of the results which were misleading by reason of the air mixing with the gas owing to openings in the junction boxes of the valves, and the leakages through the crevices in the brickwork, that he decided to make a few experiments by passing the gas through porcelain tubes which were filled with chips of porcelain in order to increase the heating surface. This was done with the object of avoiding the error due to contamination of air. He found in treating ordinary producer-gas in this way that the results were much the same as were given by Mr. Darby in his paper, but the hydrogen was somewhat at variance with the deduction which Mr. Darby made relative to ordinary producer-gas. He had found that the hydrogen had increased from 19 to 23 per cent., the carbonic acid decreased from 9 to 6 per cent., and the marsh gas, which originally was 2 per cent., became all decomposed. These changes in composition he found did not take place much below 650° C., but when the tube was heated up to 1000° C., the whole of the marsh gas was decomposed at that temperature, besides the other changes which had been pointed out. The decomposition of carbonic acid was accompanied by the formation of water vapour, and although it looked at first as though they had actually gained in the calories, they should

* *Transactions*, vol. xxii., 1893, p. 345.

bear in mind that that had been done by the absorption of heat from the checkered brickwork. This subject was one that was apt to lure one on to many speculations, and one was somewhat afraid to continue in the presence of Sir Lowthian Bell, who, they knew, was so ably fitted to deal with all questions affecting the theories of the heat development of fuel consumptions.

Touching on the effect of the steam of this water vapour and its being due to special conditions, he had found that really it was not of such serious moment as was supposed by some people. In order to prove that in a practical way, he placed an inch steam-pipe in a regenerator chamber, and, judging practically by the intensity of the flame burning in the furnace—on looking through blue spectacles he thought that any one who had had a fair amount of practice in that particular method could judge very efficiently by that—the loss of intensity was not such that one need have much apprehension of water vapour, if the checkered brickwork were not cooled down. He need hardly say that if the steam were continued it would ultimately so cool down the chambers as to defeat the object that they had in view of making steel. In the total calorific value of the gases given by Mr. Darby it would be noticed that there was an increase after passing through, but theoretically there ought to be a deduction for water vapour. The deductions that Mr. Darby made were rather in agreement with the generally received opinion enunciated by Sir William Siemens that the sensible initial heat in the gas was not utilised in the furnace. That was an opinion which he thought was not altogether correct, especially now when they took into consideration the heat absorbed from chequer work in splitting up the carbonic anhydride; so that if they kept that checkered brickwork hot, by introducing a very hot gas, containing a high percentage of carbonic anhydride, that heat would be partly utilised. The greater those changes, the more was the temperature of the regenerator lowered, especially when soot was present. It was quite possible, if that went on, that the chambers would be cooled down below the temperature of the initial gases. Therefore, they had gained that heat, and it was a point of very considerable importance at the present day. Where large furnaces were used and hot gas was used he had no hesitation in admitting that there was a great loss and

a sacrifice of heat by waste gases escaping at a temperature which would certainly have shocked Sir William Siemens in his day.

He did not agree with the deduction that was made by Mr. Darby as to the increase of carbonic oxide being due to the liberated carbon from the decomposed hydrocarbons. The experiment he had himself made bore out what Professor Bauerman said. He found that in a mixture of gas containing 43 per cent. by volume of carbonic acid and 57 per cent. of pure hydrogen in passing through a tube at about 800° C., the 43 per cent. of carbonic acid was converted into 32 per cent. of carbonic acid, with 19 per cent. of carbonic oxide, and the hydrogen had fallen from 57 to 49, showing that that change took place without the pressure of the heavier hydrocarbons, but in pure hydrogen and carbonic acid. Practically, he thought it might be accepted that there was no reason why this gas should not be used for making steel. The economical problem was one that he would not presume to enter into, but the question of the necessary steam to ensure cool working was one upon which more details might be given; it was a point on which the question would hinge very materially. It had been pointed out in the paper that assuming that there was sufficient steam to make up what was additionally wanted at the producer, certain economies would follow, but he should like to know what would be the case on the other hand if they had not got this steam and had to make it specially. What would be the result then ?

Dr. MOND said that as one of the youngest members of the Institute he felt compelled to follow the behest of his old friend the Chairman. He had not, however, come to the meeting to address the members or to say very much on the subject brought before them in a very elaborate, clear, and comprehensive way by his friend Mr. Darby, of which he thought the members must have heard nearly as much as they cared to hear. He was very glad that the question of the changes of producer-gases in regenerators, which was new to him, had led to such an interesting discussion, and that Mr. Paul had been able to corroborate by his own experiments the results which Mr. Darby and one of his (Dr. Mond's) chemists had obtained, and which had certainly rather surprised him. He was not prepared to find that carbonic anhydride and hydrogen would at this temperature inter-act, and

that the carbonic acid would be reduced. If, however, one came to consider the matter, there could be no question that they were dealing here with a subtle equilibrium between carbonic acid, hydrogen, and carbonic oxide. The changes between those gases took place with very small evolutions or absorptions of heat, so that at any definite temperature any definite mixture of those gases must arrange itself in some definite way, dependent upon the temperature and the relative volumes of the gases present.

It was quite evident that in the gas ·from his producer there was more hydrogen in proportion to the carbonic oxide, and consequently more carbonic oxide was formed by the reduction of carbonic anhydride by hydrogen, while in the case of Wilson gas, the proportions being reversed, the hydrogen was increased. However, the matter required a good deal more study. With regard to his system of converting fuel into heating gas, and at the same time recovering the nitrogen of the fuel in the form of ammonia, he had worked the subject out during the last twelve years for his own purposes. For ten years it was a hard struggle, and sometimes it did not look very promising, but during the last two years he had been thoroughly satisfied with the results. He was increasing his plant, and had every reason to be satisfied with what it was doing. Nothing would give him greater pleasure than to find that his labours would benefit not only his own industry but also the very important industries which the Institute represented.

It was with this view that Mr. Darby had brought the matter before the members, and they were all extremely welcome to any amount of information that they individually desired, and could obtain, by addressing Mr. Darby, any figures or details that might interest them. But he did not think that they wanted him (Dr. Mond) to go into arithmetic with them on that occasion. On one point he wished to add to the remarks that had been made by Mr. Darby, and by several other gentlemen, whom he thanked most heartily for the kind way in which they had treated his child ; that was the perfect, continuous working of the producer, to which he attached great importance. The ashes were withdrawn in small quantities at short intervals, and as they were withdrawn the fuel followed from the hopper into the burning zone, so that they had in one cylinder, and in one apparatus, a continuous consumption of fuel, and perfectly regulated and

steady conditions, so much so that he could always depend upon gas of practically the same composition, and at the same pressure at all times.   They gasified between 150 and 160 tons of fuel per day, which they used in various departments of the works.

He might add that being able to use gas of such regular composition and of such regular supply enabled him to carry out chemical processes which it would have been utterly hopeless to try to deal with unless one had at one's disposal such regular and steady means of heating.   They regulated the amount of supply, and the pressure in the mains, simply by increasing or decreasing the speed of the blowers, which worked the producers. The plant being under absolute pressure from one end to the other, and there being always a very large reserve of fuel in the producers, there was absolutely no difficulty in that simple way in keeping the pressure as steady as it could be read.

Mr. Paul had asked for some information on the question of the quantity of steam required for recovering the ammonia. Certainly that quantity was not very important.   The quantity of steam absolutely necessary for working the producer satisfactorily without clinkering and without getting too hot amounted to about 1·8 tons of water per ton of fuel, of which one-half was recovered; so that they had 0·9 tons of water to supply to the producers from external sources.   That was about what was wanted for driving the machinery; so that to work the plant satisfactorily, irrespective of the highest yield of ammonia, the quantity of steam required was 0·9 tons of water per ton of fuel burnt.   But he had found it much more advantageous to use a larger amount of steam.   With that quantity of steam he only obtained 30 kilogrammes of sulphate of ammonia per ton of fuel, but by increasing that quantity to 1·3 or 1·4 tons per ton of fuel he had raised the yield of ammonia to 40 kilogrammes per ton of fuel.   He had found that even though the fuel cost him on an average six shillings per ton, it paid him to use the extra amount of steam.   The steam, of course, was not required under pressure, and any exhaust steam was as good for the purpose as steam direct from the boilers, and as far as he knew there was a great deal of that commodity to be found about steelworks.   As far as gentlemen in the room were concerned, he did not think the question of the cost of this extra steam would enter into their calculations.

CORRESPONDENCE.

Mr. BERNARD DAWSON pointed out that it was to be carefully noticed that whereas most manufacturers and users of gas-producers were always seeking for a type of producer which would consume the least possible quantity of steam, for a given power or speed of gasification, that in that case a very large quantity of steam had been purposely used.
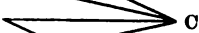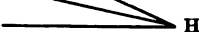
The composition of the gas from the Wilson producer, after passing up through a furnace regenerator, was a subject evidently worth further consideration.

The analysis of the dry gas from the Mond producer showed that it was very high in hydrogen and low in nitrogen, and if that type of producer were adopted in large works, it might be worth consideration whether something might be saved in areas of regenerators, flues, and valves, owing to the gas being no longer diluted to so great extent by nitrogen.

If Dr. Mond could at some future date give them the analyses of the chimney gases from this little steel furnace, with particulars of the chimney which was found necessary to work it, and also the weight of fuel per ton of steel poured, it would add to the interest and value of this important paper.

Mr. J. H. DARBY, in reply to the discussion, stated that Dr. Mond having answered the different points raised so thoroughly, it was hardly necessary for him to say much in addition. With reference to Professor Bauerman's remarks as to the change in composition in producer-gases, at his suggestion he appended the following tables, showing the gas worked into weight per cent. and the ratio of the total carbon to nitrogen before and after regenerator. It would be noticed that in both gases, from the Mond producer and from the Wilson producer, the ratio of $\frac{C}{N}$ was nearly constant, showing that the original amount of carbon had been accounted for after the regenerator, and in that way the analyses checked one another. He should point out that in the case of the Mond gas there was a shrinkage of 5·8 per cent., and in the Wilson an expansion of 1·7 per cent.

Analysis of Mond Producer Gas at Winnington.

	Volume Per Cent.	Weight by Volume.		Weight per Cent.		Σ
Before Regenerator—						
CO_2 . . .	17·8	35·20	32·54		O	30·63
CO . . .	10·5	13·21	12·21			
C_2H_4 . . .	0·7	0·88	0·81		C	16·11
CH_4 . . .	2·6	1·87	1·73			
H	24·8	2·18	2·02		H	2·57
N	43·6	54·85	50·70		N	50·7
	108·19	100·01		$\frac{C}{N} = (0\cdot317)$		100·01
After Regenerator—						
CO_2 . . .	10·5	20·77	18·62		O	27·53
CO . . .	21·6	27·18	24·47			
C_2H_4 . . .	0·4	0·50	0·45		C	16·92
CH_4 . . .	2·0	1·44	1·29			
H	17·7	1·58	1·41		H	1·79
N	47·8	60·13	53·87		N	53·87
	111·60	100·11		$\frac{C}{N} = (0\cdot315)$		100·11

Analysis of Wilson Producer Gas at Brymbo.

	Volume Per Cent.	Weight by Volume.		Weight per Cent.		Σ
Before Regenerator—						
CO_2 . . .	7·63	15·000	13·119		O	23·126
CO . . .	21·73	27·184	23·775			
C_2H_4 . . .	1·06	1·326	1·159		C	16·199
CH_4 . . .	3·05	2·180	1·906			
H	12·60	1·127	·985		H	1·625
N	53·80	67·519	59·053		N	59·053
	114·336	99·997		$\frac{C}{N} = (0\cdot274)$		100·003
After Regenerator—						
CO_2 . . .	5·19	10·203	9·638		O	23·606
CO . . .	24·79	31·012	29·294			
C_2H_4 . . .	·41	·513	·484		C	16·272
CH_4 . . .	1·33	·950	·897			
H	19·17	1·715	1·620		H	1·913
N	48·98	61·469	58·065		N	58·065
	105·862	99·998		$\frac{C}{N} = (0\cdot280)$		99·856

It was stated by Mr. Paul that he found in his experiments that there was practically no alteration in the composition of producer-gases when passed through a porcelain tube at a temperature of 800°, but at 1000° there was a change. The initial heat in producer-gases entering a regenerative chamber was never over 800° C., therefore his argument as to the heated lower portion of regenerative chambers doing work on producer-gas by changing composition, as mentioned, did not appear to be correct, and he (Mr. Darby) maintained what he had previously stated, that the initial heat in gas leaving the producer was not utilised in the regenerative steel furnace. The calorific values given were only comparative and not absolute, but for the object they were used they were practically correct.

Replying to Mr. Dawson, he remarked that the chimney gases of the small experimental steel furnace contained 14·9 per cent. by volume of carbonic anhydride and 4·8 per cent. of oxygen when the furnace was working under normal conditions. The height of the chimney employed was 70 feet and the diameter 3 feet; the draught measured on the same level as the charging platform was equal to 11 to 13 millimetres of water. The consumption of fuel per ton of steel produced was very low taking into consideration the size of the furnace.

The CHAIRMAN said it was his duty to ask the members to accord a vote of thanks to Mr. Darby for his very excellent paper, and he would include in the proposal the name of Dr. Mond, to whom they were indebted for having kindly come forward to treat the members with so much candour as he had done upon the present occasion.

The vote of thanks was carried by acclamation, and the following papers were read :—

FURTHER NOTES ON THE HARDENING OF STEEL.

By HENRY M. HOWE (Boston, Mass.) and ALBERT SAUVEUR
(South Chicago, Illinois).

This paper gives and discusses the results of a microscopic examination of twenty-one $\frac{5}{16}$th-inch square bars of the same low carbon steel, which, as is set forth in a previous paper * by one of us, starting from the same initial condition, were heated to very nearly the same temperature (970° C.), then cooled slowly to a series of points in and near the critical range (say 700° to 580° C.), and there quickly quenched in cold brine, in order by this sudden cooling to fix the condition existing at these several points in this range.

The structure of certain typical bars of this series is shown by Figs. 2 to 10 inclusive, Plate VIII., and the results of this examination are given in Table I., and graphically in Plate VII.† The structure of the bars intermediate between those sketched in Figs. 2 to 10 is shown sufficiently by these figures. Thus bars 21 and 10 are closely like bar 14, and bars 8, 13, 17, 20, and 23 are like bar 19.

Definitions.—We use Osmond's name, "Martensite," for the

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* "The Hardening of Steel," by Henry M. Howe, *Journal of the Iron and Steel Institute,* 1895, No. II., p. 258. We shall refer to this as "the previous paper."

† These sketches, which are magnified by 125 diameters, for closer comparableness, represent the structure of the centre of the cross-section of the several bars, though, perhaps owing to the small size of these bars, their structure is practically alike in all parts of their cross-section, except very near the outside, which possibly may be slightly decarburised.

The areas given in Table I. are based on planimeter measurements of sections four times as large as those given in the sketches Figs. 2 to 10.

In order to bring out clearly the relations between the areas occupied by each of the constituents, we omit all indications of the structure of the martensite and of the segregated ferrite, the latter of which, as is well known, consists of crystalline grains, probably interfering crystals of the monometric system.

One of us finds strong indications that the martensite is composed of two substances differing considerably in hardness. Indeed, Mr. Osmond, in his admirable description of it, expressed his doubts as to whether it was a "primary constituent" (*Méthode Générale pour l'Analyse Micrographique des Aciers au Carbone,* p. 18, 1895). We adopt the name "Martensite" without thereby assenting to any theory as to the nature of this substance.

TABLE I.—*Influence of Quenching Temperature on the Physical Properties, various quenching ... of Steel of 0·21 per cent. of Carbon.*

No.	Quenching Temperature, Degrees C.		Tenacity, Pounds per Square Inch.	Hardness, Width of Scratch, mm.	Elongation		Contraction of Area, per Cent.	Missing Carbon, per Cent.	Micro-structural Composition, per Cent.		
					Per Cent.	Inches.			Martensite.	Pearlyte.	Perlite.
6	880	Above Ar₃	224,600	...	8·50	2·5	...	0·092	100		
7	836		207,500	0·0276	3·00	4	5·	0·095	"		
4	797		218,200	0·0285	6·00	4	...	0·102	"	0	0
16	761		193,516	...	1·25	4	1·01	0·082	"		
15	733		220,898	0·0290	4·50	4	...	0·095	"		
12	714	Beginning of Ar₂	221,300	0·0281	7·50	4	...	0·102	97·20		2·80
18	713		211,316	0·0303	2·50	4	1·54	0·093	86·00		14·00
9	698	Middle of Ar₂	206,673	0·0293	3·75	4	3·53	0·096	70·20	0	29·80
5	652	Between Ar₂ and Ar₁	145,000	...	2·25	4	3·17	0·100	35·20		64·80
14	650		142,000	0·0298	4·75	4	5·68	0·084	30·80		69·20
21	633		128,237	0·0333	4·25	4	5·87	0·064	32·00		68·00
10	626		125,756	0·0320	5·50	4	5·94	0·084	31·50		68·50
22	620	Beginning of Ar₁	121,058	0·0329	6·25	4	5·60	0·091	30·00	1·60	68·40
11	600	End of Ar₁	91,600	0·0333	13·50	4	44·40	0·034	4·00	17·50	78·50
3	599		89,000	0·0332	13·00	4	46·50	0·047	2·00	22·20	75·80
8	575	Below Ar₁	93,400	0·0343	19·75	4	38·60	0·029		21·10	78·90
19	532		82,771	0·0343	21·25	4	51·34	0·005		23·20	76·80
13	512		82,100	0·0356	26·00	4	54·40	0·018	0	23·00	77·00
17	340		79,362	...	23·75	4	53·54	0·000		22·60	77·40
20	263		76,523	0·0365	22·50	4	55·64	0·000		24·80	75·20
23	20		73,956	...	25·75	4	52·29	0·008		23·60	76·40
24	Not treated at all		93,707	0·0331	18·75	4	53·89	...			
25			94,340		17·50	4	51·14				
Total loss or gain	...	...	150,644	0·0089	22·75	...	...	0·102	...	...	...

Average 0·094

hard substance which composes hardened steel, and for the two substances which chiefly compose unhardened steel we use the established names " Ferrite " and " Pearlyte," of which the former appears to be nearly pure iron, the latter an intimate mixture, often in parallel striæ, of this ferrite with an intensely hard iron carbide, " Cementite," probably of the composition Fe_3C.

The distribution of these two substances in our unhardened steel is shown in Fig. 10, in which the ferrite forms the matrix, and the pearlyte the porphyritic grains distributed through it.

To distinguish the ferrite which forms the matrix from that which forms parts of the pearlyte, we call the former " segregated ferrite."

Of the two retardations which occur spontaneously in this range of temperature when this steel is allowed to cool slowly and without disturbance from outside, we call the upper Ar_2, and the lower Ar_1, following Osmond's notation.

TABLE II.—*Condensed Statement of Results.*

Range Represented.				Corresponding Changes in the Various Properties.					
Bars Represented.		Quenching Temperature.		Loss of Tenacity, Lbs. per Sq. Inch.	Gains in Elongation per 100 of Initial Length.	Loss of Hardness, = Gain in Width of Scratch.	Gain in Colour Carbon.	Structural Change. Increase in Percentage of	
From Bar No.	To Bar No.	Position in Cooling Curve.	Degrees C.					Ferrite.	Pearlyte.
15	9	Beginning and middle of Ar_2	733 to 698	...	− 0·75	·0003	− ·001	31·6	...
9	5	End of Ar_2	698 to 652	61,673	− 1·50	·0027	− ·004	33·2	...
5	10	Between Ar_2 and Ar_1	652 to 626	19,244	+ 3·25		+ ·016	3·7	...
10	3	Ar_1	626 to 599	36,756	+ 7·50	·0012	+ ·037	7·3	22·2
3	23	Below Ar_1	599 to 20	15,044	+ 12·75	·0033	+ ·039	0·6	1·4

General Description of Results.—Above Ar_2 the steel consists wholly of martensite, of which about 64 per cent. changes to ferrite at and just below Ar_2. The structure now remains nearly constant till the quenching temperature sinks to Ar_1, when the remaining 30 per cent. of martensite disappears, yielding about 22 per cent. of pearlyte, and about 7 per cent. more of segre-

gated ferrite, and thus bringing the total quantity of this latter substance up to about 75 per cent.

As is to be expected from the shape of the cooling curves, these changes are far from instantaneous.   The change from martensite to segregated ferrite at Ar_2 spreads out over at least 62°, and that at Ar_1, while apparently more sudden, still covers at least 20°.

Osmond had reported that the well-known change of carbon condition from hardening to non-hardening or cement which occurs during slow cooling, took place at Ar_1, and the results in the previous paper confirm this.*   For, rather strange to say, the great change from martensite to ferrite at Ar_2 is accompanied by no change in the condition of carbon, so far as this is revealed by the Eggertz method.

The change of the first 30 per cent. of martensite to ferrite (bars 15 to 9), on the upper slope of Ar_2 is accompanied by no considerable change in tenacity or ductility ; for even bar 9, with nearly 30 per cent. of ferrite scattered through it (Fig. 5), does not differ· materially in these properties from some of those quenched at higher temperatures, with less, or even with no ferrite.   (See Table I.)   Bar 9 is, indeed, some 14,000 lbs. weaker than bar 15, but it is almost as strong as bar 7, and stronger than bar 16.

In the 46° next below this (bars 9 to 5), including the lower slope of Ar_2, though the further change from martensite to ferrite is but slightly more than in the preceding higher range, though there is no appreciable change in the carbon condition as shown by the Eggertz test, and though the ductility remains nearly constant, the tenacity falls off abruptly by some 60,000 lbs. per square inch, or say 30 per cent.   (See Table II.)

In the next 26°, between Ar_2 and Ar_1 (bars 5 to 10), the tena-

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* Osmond and Werth showed that the attack by nitric acid volatilises part of the "hardening" carbon : hence the depth of colour which the Eggertz method gives to a nitric acid solution is less in case of hardened steel, *i.e.*, steel of which the carbon is in the hardening state, than in the case of the same steel when slowly cooled.   The difference between the carbon found by this coloration test in any given piece of steel, and that which this method gives in the same steel when cooled slowly, or the "missing carbon" as it has been called, is a rough measure of the quantity of carbon present in the hardening state.   Now the change in the quantity of missing carbon occurs almost wholly at Ar_1, whence we infer that it is here that the condition of the carbon changes from hardening to cement.

city progressively falls off further by some 20,000 lbs., and the hardness diminishes, but without material change in structure, and still without considerable change in ductility or carbon condition.

At Ar_1 (bars 10 to 3), where the remaining martensite changes to pearlyte, and below it (bars 3 to 23), the tenacity falls off greatly, and with it the hardness ; and here, at last, the ductility increases rapidly, and the carbon condition also changes markedly.

We may, in short, recognise six ranges :—

1. Above Ar_2, where no marked change occurs.

2. The upper part of Ar_2, with a great change of martensite to ferrite, and no other change clearly marked.

3. The lower part of Ar_2, with further great change from martensite to ferrite, and with great loss of tenacity.

4. Between Ar_2 and Ar_1, with no marked change except a considerable loss of tenacity and of hardness.

5. Ar_1, with a great change from martensite to pearlyte, a great loss of tenacity, a slight loss of hardness, a moderate gain in ductility, and a marked change in carbon condition. And,

6. Below Ar_1, with no further change in structure, but with a considerable loss of tenacity, a great gain in ductility, a great loss of hardness, and a marked change in carbon condition.

DISCUSSION OF THE RESULTS.

The structural changes seem to coincide closely with the retardations, but not with the changes in the physical properties. Thus, while the structural change at Ar_1 is certainly accompanied by a marked loss of tenacity and change in carbon condition, as well as by a moderate gain in ductility and loss of hardness, and while the latter half of the structural change at Ar_2 is accompanied by a very great loss of tenacity, yet the first half of this structural change at Ar_2 is accompanied by no clearly marked change in any of the physical properties. Between Ar_2 and Ar_1, on the other hand, where there is neither retardation nor marked structural change, there is a decided loss of tenacity ; and after the end of the structural change at Ar_1, there is a considerable loss of tenacity, a marked increase in ductility, a great

loss of hardness, and a great change in carbon condition.   While we are not disposed to insist on these discrepancies, recognising that considerable variations in these physical properties may be expected even when the conditions of treatment are purposely made closely alike—as, for instance, is the case with bars 12 and 18; yet, in view of the close agreement between the other sets of bars which, in these tests, have been treated alike, viz., bars 5 and 14, 11 and 3, 24 and 25, we think that these discrepancies deserve attention.   The contrast between the slight loss in tenacity accompanying the first, and the great loss accompanying the last half of the structural change at Ar_2, in view of the amount and regularity of the further loss of tenacity below Ar_2 without structural change, and the contrast between the slight gain in elongation (7·5 per cent.) as the pearlyte rises at Ar_1 from nil to 22·2 per cent., and the amount (12·75 per cent.) and tolerable regularity of its further gain, as the pearlyte below Ar_1 further increases by, at most, 1 or 2 per cent. :—these contrasts are too marked to be ignored.

In view of its bearing on the allotropic theory of the hardening of steel, our most important observation, we think, is the coincidence between the retardation at Ar_2, and the separation of a great quantity of ferrite from the martensite, which, above that point, had formed the whole mass of the steel.

The fact, first established in the previous paper, that the retardation at Ar_2 though apparently unaccompanied by any change in the condition of carbon, was yet followed by a very great loss of tenacity, was thought to point to an allotropic change in the iron itself, as the cause of the retardation and of the loss of tenacity.   The present results put the matter in a somewhat different light.

On one hand, the opponents of allotropy (homœotropists?) may say, " The proved structural change suffices to account for the retardation, the loss of tenacity, and any other physical changes at Ar_2, so that allotropy becomes a superfluous explanation."

To this the allotropists may say, " The structural change itself, and especially the suddenness with which it takes place, is evidence of allotropy.   Were the iron to remain in the same allotropic (or, if you prefer, molecular) condition, it either would not separate at all from the martensite, or would separate pro-

gressively, not with a bound.   Thus when two gases, dissociated by heat, are gradually cooled, they combine progressively, according to the temperature and vapour tension and without retardation. But when, as in the freezing of one component of a mixed liquid, there is a change of state, then indeed we get such sudden evolutions of heat as to cause a retardation.   Retardations, then, as evidences of supersaturation, are tokens of a change of state of one of the components, be it a change from liquid to solid, or from one allotropic state to another,

"The retardations in perfectly carbonless iron must be referred to allotropic change.[*]   This, then, is the change of state which underlies the retardations in carbon-bearing iron, and among other things causes the separation of ferrite from martensite at Ar_2. This separation of ferrite may, indeed, augment both the retardation and the changes in the physical properties; but the underlying cause of all is an allotropic change in the iron itself."

In this connection we call attention to an observation which has surprised us.   It is not easy to see how isolated grains of sand, of steel, or of other foreign body, mechanically mixed through a mass of putty, can materially strengthen that putty tensilely.   They may interfere with its ductility; if themselves of sawdust, and therefore weaker than the putty, or if the putty does not adhere tenaciously to them, then they may weaken it; but how they are to strengthen it materially we do not see. Neither do we see how grains of martensite or of pearlyte, if isolated, suspended in a matrix of ferrite, can materially increase the tenacity of that matrix.

Applying this to the present case, we notice that all the bars quenched from 650° or below, appear to consist of a matrix of ferrite, in which are porphyritically distributed isolated grains, first of martensite, then of both this compound and pearlyte, and finally of pearlyte alone.   Now, while we can see that this mechanical admixture of these grains should interfere greatly with the ductility of the bar as a whole (dimly understanding that even so small a quantity as 2 per cent. of the brittle martensite might, as in bar 3, bring the elongation down to about

* Two upper retardations, Ar_2 and Ar_3, were detected in iron in which a rigorous search failed to detect any carbon.   Roberts-Austen, *Proc. Inst. Mechanical Engineers*, April 26, 1895, p. 244.

PLATE VII.

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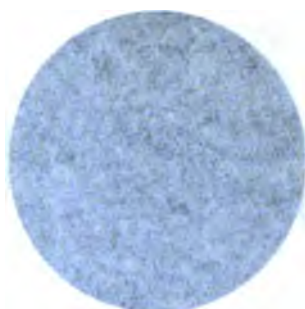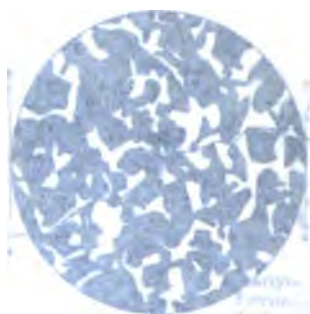
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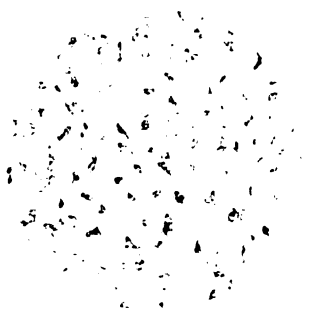
half that of the slowly cooled metal), we yet fail to see how they can materially increase its tenacity.

Inferring from the great tenacity of the bars which contain martensite alone, that this substance is very much stronger than ferrite, it is to be supposed that when a bar like number 14 (Fig. 6) is torn in two tensilely, as indicated by the arrow heads, rupture will pass through the relatively weak ferrite by a path something like EF. Such a path is only 2 per cent. longer than a line drawn straight across from AB perpendicularly to CD. Should rupture follow a surface the average length and breadth of which were equal to EF, then that surface would be only 4 per cent. greater than a plane cut straight across the bar.

If now the ferrite of this bar 14 were, as is supposed, practically pure iron, and therefore like the softest ingot iron, with a tenacity of at most some 50,000 lbs. per square inch, the tenacity of this bar should not be more than 4 per cent. greater, or 52,000 lbs., while actually it is 142,000 lbs., or nearly thrice as great.

But even were this ferrite as strong as that of bar 23, the strength of bar 14 should be only about 4 per cent. greater than 73,956 lbs., or say 77,000 lbs., while actually it is 142,000 lbs., or nearly twice as great. This difference we find it hard to account for on merely mechanical grounds, either by the presence of the isolated grains of martensite or by the stress induced by quenching, especially in view of the fact that quenching induces no comparable strengthening, so far as we know, in any substance other than iron.

It therefore appears to us that this ferrite of bar 14 is about thrice as strong as that of soft ingot iron, and about twice as strong as that of this same steel when cooled slowly. It appears also to be less ductile than these other forms of ferrite. We have thus far been unable to detect microscopically any difference between these different lots of ferrite which seem to differ so greatly in tenacity; nor could Mr. Osmond, who has kindly examined some of these bars for us, with this particular point in view, detect any such difference.

Like reasoning applies to the bars quenched below 650°. So, too, if we take bar 9, quenched at 698° C., and assume that its martensite is as strong as that of the bars quenched above Ar_2,

then rupture, following a line something like that in Fig. 5, so as
to avoid the strong martensite and pass through the weak ferrite,
would pass through martensite and ferrite enough to call for a
tenacity of about 100,000 lbs. per square inch, while the actual
tenacity is more than 200,000 lbs. per square inch.

Two explanations suggest themselves. The ferrite, instead of
being practically carbonless as has been supposed, may contain
an amount of carbon which varies with the surrounding condi-
tions, the carbon distributing itself between the ferrite and the
other constituents (martensite and pearlyte) in proportions which
yield equilibrium, and which vary with the total quantity of
carbon present, and with the temperature, pressure, &c.   Or,
following Osmond, there may be two allotropic or at least mole-
cular varieties of ferrite, a hard, brittle β variety, stable at
high temperatures, preserved more or less completely by sudden
cooling, and changing gradually to the soft, weak a variety
during slow cooling, a change retarded catalytically by the pre-
sence of carbon, and underlying the retardation at Ar_2 and the
separation of ferrite at that point.

Against the former explanation it may be urged with force that
the apparent very great weakening of the ferrite between 698°
(bar 9) and 620° (bar 22) is accompanied by no apparent change
in carbon condition, such as we should look for were the quantity
of carbon in the ferrite to change.   This consideration, coupled
with the other discrepancies between structural change and physical
properties, lends colour to the explanation that these successive
retardations and their accompanying phenomena are due pri-
marily to changes in the nature of the iron itself, which there-
fore are the real causes of the structural changes and the change
in carbon-condition, in tenacity, hardness, &c.

These suggestions are offered in the hope that they may aid in
finding the true explanation of this complex matter. We will
not dignify them with the name of hypothesis, much less with
that of theory, believing that an unfortunate effect of insisting
prematurely on theories is to bias the theoriser for, and almost
everybody else against, his theory, and thus to interfere with the
judicial frame of mind in which these questions should be ap-
proached.

For the same reason we express no opinion here as to the merits of the allotropic theory, preferring to await further information, and especially because we are ourselves studying microscopically a matter which has lent this theory one of its very strongest supports, viz., the great strengthening which almost carbonless iron undergoes on quenching.

NOTE ON MR. HOWE'S RESEARCHES ON THE HARDENING OF STEEL.

By F. OSMOND, Paris.

I HAVE read and studied with great pleasure the work of Mr. Howe on the Hardening of Steel. The author, with complete mastery of his subject, has chosen the best experimental conditions for arriving at conclusive results, and he has succeeded, where others have failed, in demonstrating the complexity of the phenomena of hardening, and in connecting the critical points of soft steels with the variations in their mechanical properties.

The critical portion of his paper is a model of lucidity, logic, and equity. It is true that certain divergences of opinion may still remain; but the work as a whole presents such an imposing front, that observations on points of detail run the risk of appearing trifling. It is preferable to accept Mr. Howe's arguments as a faithful exposition of the respective positions of current theories. On this basis an endeavour may be made to ascertain how far the allotropic theory can, by the natural development of the consequences to which its principle leads, remove the objections which might justly have been urged against it in its primitive form.

When the allotropic theory was originated, it seemed well, for the sake of simplicity and in the absence of decisive adverse reasons, to unite and consider as parts of a single phenomenon the two points a_2 and $\grave{a}_3$. But these two points became definitively separated directly it was shown that one only of them, a_2, coincides, to the exclusion of the other, with the appearance or disappearance of magnetism in iron. From that time it was necessary to distinguish at least three molecular states of iron, which were respectively stable within certain intervals of temperature: a below 700°, β between a range of 750° to 860°, γ above 860°.*

* It may be well to recall the fact that the experiments of Dr. Ball (*Journal of the Iron and Steel Institute*, 1890, No. I. p. 85) indicate the possible existence of a new critical point near 1300°.

If it is now possible, by suitable devices, to preserve at the ordinary temperature the two forms of iron which are not usually and naturally found in equilibrium, we may expect to find, among the innumerable varieties of steel, three general and well distinct types in which the a, β, or γ modifications dominate respectively and assert their presence.

Further, it appears easy to show that these three types of steel really exist, and that they well represent the existence of each of these forms of iron, independently of the means employed to maintain the forms distinct.

Consider the case of iron alloyed with elements of small atomic volume.   We know that, in accordance with Roberts-Austen's law, which has been verified by experiment, such elements lower, and even go far to suppress the points of transformation; and among these elements there are three—carbon, nickel, and manganese—which play a most important part in metallurgy, and concerning which there is much documentary evidence, published or otherwise.

Only it is necessary to compare comparable things.   Of the three elements under consideration, there is one—carbon—which has the property of forming during the slow cooling of iron a definite compound with iron, capable of isolating itself in the mass.   With nickel and manganese, which remain active, we cannot compare the inert carbon, which is isolated under the form of a carbide of iron, but only the kind of carbon of which the activity is preserved by quenching, although we do not know exactly its true nature.   In other words (and it is a necessity which is constantly ignored), only hardened carbon steels can legitimately be brought in line with the manganese steels or nickel steels; and the annealed carbon steels should therefore be deliberately set aside, paradoxical as it may seem to those metallurgists who think that different metals can be made comparable by subjecting them to identical treatment, not recognising that they often thereby obtain precisely the contrary results.

Let us then increase continuously, in three parallel series, the proportions of nickel, manganese, or active-carbon, and see how the critical points and the essential physical properties may be correlated.

Nickel Steels.—The case of nickel is really the most simple,

because nickel steels poor in carbon can be obtained, and because we owe, more especially to the researches, always so methodical and so useful, of Mr. Hadfield,* and to those of the *Compagnie des Aciéries de St. Etienne,* series of very suitable specimens in which the amount of carbon present is very small.

In these series the tensile strength of annealed test - pieces rises at first with the amount of nickel, while the extensibility correspondingly decreases.

Between about 10 (or 12) and 24 per cent. of nickel the tenacity remains near a maximum, and the ductility near a minimum.   Then, near 25 per cent. of nickel, the resistance is lowered and the extensibility is increased.

The series may, therefore, be subdivided into three groups.   In the first, the critical points, which are at the outset separated, reunite and become progressively lowered, and occur between 500° and 515° in the case of steel with 7·65 of nickel; the hardness to the file (except perhaps that of the extreme members of the series, which I do not possess) does not appear to differ from the hardness of ordinary steels, and (with the same reservation) short bars do not appear to be permanently magnetic.

In the second group the point of transformation falls below 350° or 400°.   In the case of 15·48 per cent. of nickel it falls to between 130° and 120°, and with 19·64 per cent. of nickel it falls to between 85° and 65°.   The transformation in the case of steel with 24·51 per cent. of nickel is incomplete even at the ordinary temperature.   At the same time the hardness increases greatly; and although the hardness of quenched high-carbon steels is not attained, it is practically very difficult to work this variety of steel with tools, and short bars are permanently magnetic.   It is easy to show that the point at which hardness is acquired coincides with the evolution of heat during cooling.

With about 25 per cent. of nickel or a little more, no critical point can be observed during slow cooling; the mineralogical hardness is slight, working with tools is possible, if not easy, and the metal is practically non-magnetic.

It is, moreover, easy to see that in the series of St. Etienne steels the tensile strength varies inversely as the percentage of carbon in the case of metals with 25 per cent. of nickel which

* *Comptes Rendus de l'Académie des Sciences,* vol. cxviii. p. 532.

have been either annealed or quenched in water. In the series
with 15 per cent. of nickel, the tensile strength, after having
increased simultaneously with the carbon, then diminishes rapidly,
as successive additions of carbon are made.

Manganese Steels.—As regards these steels the results are not
so clear and are less conclusive, for we do not possess a regular
series of them with a small percentage of carbon, and it is impos-
sible, therefore, in each particular case, to apportion the influence
which is exerted respectively by carbon and by manganese.

It is, however, known that up to about 3·50 per cent. of man-
ganese, typical properties—that is to say, mineralogical hardness
and magnetic qualities—do not appear to undergo any radical
change.

The iron alloys with the above proportions of manganese have
critical points above 400°.

With about 3·50 per cent. of manganese, steels are met with
which may be made either hard or soft at will. I am indebted
to Mr. Hadfield for a specimen containing, C = 0·30, Si = 0·18,
Mn = 3·25 (or 3·89 according to another analysis). This metal,
which I received in the form of a small forged bar, was found
to be very hard. After heating to a temperature of 800°, and
allowing it to cool spontaneously in a Leclerq and Forquignon
furnace, treatment which revealed the existence of a critical point
at about 400°, it was softened, but still remained fairly hard.
After heating a second time (in this instance up to 1000°), and
cooling it under the same conditions, when the critical point
proved to be at 425°, it became soft enough to file readily.

With between 3·50 and 7·00 per cent. of manganese, steels are
obtained which, when slowly cooled, scratch glass and become per-
manent magnets, their point of transformation then being lowered
below 400°.

I may cite, as examples, two specimens which have also been
furnished me by Mr. Hadfield (together with their analyses) which
contain respectively—

	Carbon.	Silicon.	Manganese.
No. 34	0·45	0·11	4·00
No. 32	0·32	0·26	{ 5·04 { 6·31

No. 34 has its point of transformation between 300° and 200°,
and that of No. 32 is below 100°.

I am aware that Mr. Hadfield, during a recent discussion, produced two alloys each containing 3·50 per cent. of manganese, and 0·10 and 0·54 per cent. of carbon respectively; the first could be filed easily, but the second not at all; hence Mr. Hadfield concluded that carbon alone imparts hardness to the alloy, and consequently that the advocates of allotropy are wrong. But I have two other steels, which also came from Mr. Hadfield's collections, which contain—

	Carbon.	Silicon.	Manganese.
No. 309.	0·33	0·86	3·67
No. 311.	1·00	0·72	3·76

If these two varieties of steel are allowed to cool slowly from the same initial temperature of about 1000°, the first, which contains 0·33 per cent. of carbon, will scratch glass, while the second, with 1·00 per cent. of carbon, can be easily filed, from which I might infer, by adopting Mr. Hadfield's reasoning, that carbon destroys hardness, but this conclusion I shall take good care to reject. If, however, 7 per cent. of manganese be exceeded, and 12 or 13 per cent. be reached, we are in presence of Mr. Hadfield's well-known metal, which is difficult to file, though it does not possess great mineralogical hardness, and is susceptible of considerable elongation without local contraction of sectional area, is non-magnetic, and does not exhibit any notable critical point during slow cooling.

Quenching has no further effect on this metal than to hinder the liquation of the double carbide of iron and manganese, which forms a continuous network round the grains of the steel which has been slowly cooled.

Carbon Steels.—As I have already explained, I ought only to deal with those steels which have been hardened, and in order to avoid mixtures of martensite with ferrite or cementite, it is desirable that the hardening should be effected as quickly as possible, care being taken to employ a degree of temperature which is sufficient to ensure the complete diffusion of the carbon.

Under these conditions it is known that mineralogical hardness increases with the carbon (in accordance with a law which is imperfectly understood), from the hardness presented by soft iron to that of orthoclase; the residual magnetism also increases, at

first, proportionately with the carbon. These two variables appear to attain a maximum with a percentage of carbon, which has not been accurately fixed, but which is not far from one per cent. Under these conditions the heat of the transformations which are not suppressed by the quenching ought to be evolved (at least in the case of high carbon steels) at the ordinary temperature. Mr. H. Le Chatelier's researches on the variations of electric resistance produced by hardening have shown that this should be the case.[*]

As the carbon rises above about one per cent., a new constituent, recently described by me, appears, and this I have called "*austenite*," as a souvenir of the great part taken by Professor Roberts-Austen in establishing the allotropic theory. The proportion of austenite increases until the percentage of carbon reaches about 1·60 per cent., but the total amount of it present cannot exceed a certain maximum (in round numbers, 50 per cent. of the mass), and this amount remains limited by the formation of cementite. Its properties, as far as can be determined from its presence in a mixture, approach nearly to those of steel with 12–13 per cent. of manganese and to the steel with 25 per cent. of nickel.[†]

Conclusion.—The accepted facts tend to establish the parallelism of the three series—that is, of nickel, manganese, and carbon steels.

In each series is to be found :—

1. A group of steels which are soft, magnetic, and are not polar-magnetic, or hardly so when the metal is in the form of short bars.

2. A group of steels which are either absolutely or relatively hard, are magnetic and polar-magnetic.

3. A group (or the representative of a group) of steels which are difficult to work in the cold, do not possess much mineralogical hardness, and are extensible and non-magnetic.

The metals of the first group have well-defined and perfect critical points, which occur above 400°; the bulk of the iron is in its normal state—the a state.

The metals of the third group do not possess a transformation point at all, the iron then is present in the form which is by

* *Comptes Rendus de l'Académie des Sciences,* vol. cxii. p. 40.
† *Ibid.*, vol. cxxi. p. 684.

definition the γ modification. In view of the point discovered by Dr. Ball, and confirmed by Mr. Curie, the question arises whether it may not ultimately be necessary to divide the γ modification into two. But the existence of iron in an allotropic form in non-magnetic steels, although it may be still rejected by some metallurgists, has nevertheless been established with such a degree of precision and certainty as the demonstrations of chemical science allow.

As regards the second group, that of the hard and polar-magnetic steels, I attribute their characteristic properties to the maintenance of a part of the iron in the β form, the transformation of β into α iron being limited by the pressure which results from a change in volume, exactly as partial volatilisation limits the evaporation of water in a closed vessel. But it is true that the question still retains a certain amount of residual hypothesis.

Experiments show that in the case of metals of this group, the transformations take place below $350°$ or $400°$; that is to say, below the temperature at which tempering obliterates in carbon steels the greater part of the effects of hardening. The subsisting hypothesis consists in admitting that in these conditions the transformations of iron are incomplete, which seems very probable, for we cannot understand otherwise the break which appears to exist between the two first groups. In order to prove this experimentally, it should be necessary to measure (1) the quantities of heat normally evolved at points Ar_2 and Ar_3 during the cooling of pure iron; (2) the quantity of heat actually evolved when these two points are united in a single point, $Ar_{3\cdot2}$, in steels which remain "glass-hard" after slow cooling; and (3) to show that the second is smaller than the sum of the two first, that is, of Ar_2 and Ar_3 separately. But this comparison, which seems easy in theory, becomes much less easy in practice, for two reasons :—(1) No exact method is known for converting into calories the evolutions of heat represented by the delays observed during cooling; (2) even if there were such a method of procedure, it would still be necessary to know how the heat of the transformation varies with the temperature at which the transformations are produced. Recourse can only be had, therefore, to direct examination of the curves, and this examination is

necessarily insufficient. In fact, whilst admitting that the transformation of β into α may be incomplete, this transformation is, however, partial (since glass-hard steels are magnetic, and their being magnetic involves the supposition that α iron is present), and further, the transformation is blended in the metals in question with the point Ar_3. The portion of Ar_2 which is supposed to be suppressed can only, then, be a small portion of the heat really evolved, which includes and represents the total transformation of γ into β and the partial transformation of β into α. Inspection of the curves cannot show a difference of this kind, and in fact does not really indicate it.

I regret that I am not able to furnish more complete documentary evidence. I think, however, that the facts are already capable of being grouped in a satisfactory way, and that the distinction established between γ and β iron, which is not an arbitrary, but an experimental one, will cause the difficulties to disappear which arose, after the discovery of manganese and nickel steel, from the primitive confusion between the two varieties.

Mr. Howe's memoir does not, moreover, permit us to delay the exposition of these ideas. If the explanation now offered seems premature, it will at least furnish a programme of fresh researches which I cannot hope to complete unaided.

However, do the explanations given show that there is room for the introduction of a carbo-allotropic theory such as Mr. Howe has sketched? I do not hesitate to reply in the affirmative, in the sense that carbon presents, in its relations with iron, a certain number of peculiarities which are inseparable from its presence. It is even necessary, strictly speaking, to contemplate a theory for each of the bodies which we have considered which would point to nickelo-allotropic and mangano-allotropic theories.

The allotropic theory, as I hope I have shown, enables the dominant facts and general history of steels to be synthetised, but it must differentiate itself effectively in connection with special facts.

Furthermore, I ask Mr. Howe to permit me to welcome the carbo-allotropic theory, whatever its future development may be, not as a rival theory, but as a friend and ally.

DISCUSSION.

Mr. R. A. HADFIELD, Member of Council, considered that the papers and communications by Messrs. Howe, Sauveur, and Osmond, notwithstanding their interest, would no doubt lead members of this Institute to wish that this continued controversy concerning iron and carbon, and as to whether allotropy or homeotropy should win the day, would show some signs of approaching solution, or that some new definite facts be placed before them for consideration.

In the first place, let him say that those who do not accept allotropy were anxious to give credit in every possible way for the laborious and painstaking research work their opponents had undertaken on behalf of what they considered the truth.   He, for one, should do his utmost to wage battle on the most friendly lines, only asking in return that they should be given the same credit for wishing to arrive at a satisfactory solution of that interesting but exceedingly complex question.   There was no reason why such discussions as those should not be conducted on good-humoured and friendly lines.   In any case both sides were collecting interesting data which would be useful for the metallurgists of the future.

To sum up briefly respecting those three papers, it seemed to him that there was not a single further point raised by their opponents which met the facts stated in the papers contributed by Messrs. Arnold and himself some two years ago, and the still later exceedingly valuable research work presented by Professor Arnold to the Institution of Civil Engineers on " The Influence of Carbon upon Iron."

Nay, more, he thought their opponents had distinctly retrograded in the strength of their arguments, and from the position they occupied two years ago.   The more their theories were examined in the light of present knowledge and latest facts, the less tenable did they seem.   His friend Mr. Howe, one of the most amiable of men, who tried so hard to conciliate both sides, had at last jumped off the fence, in order not to take a particular view, so he said, but evidently to try and sit on the two stools of " carbo-allotropy," with, so it seemed to him, the result of " coming to the ground."   Any one who had carefully studied his

papers could not but be struck with the extraordinary capacity and ability he had shown in formulating complex explanations. But it did seem that a case for his own and the theories of others he represented, if clear, should not have required such extremely elaborate, almost laboured, explanations.

In the first place, were the authors for or against allotropy? They claimed to be neutral, but any one carefully reading the papers could not but arrive at the conclusion that in their hands was held a brief for allotropy. Their opponents evidently thought so, as they had publicly welcomed and claimed Mr. Howe as one of themselves.

In the second place, the authors' experiments were based upon a material which was termed "low-carbon steel." Seeing that the carbon, silicon, and manganese amounted to no less than 1·71 per cent., according to their own analyses, such a material could not be considered a low-carbon steel in the ordinary sense of the term.

Besides, too, the extremely powerful stiffening element, manganese, was present in the comparatively large proportion of 1·19 per cent. In face of a sample to which he should shortly refer, where about 3½ per cent. of manganese, with about 0·65 per cent. carbon, gave, without any rapid cooling or even quenching, a glass-scratching material, no wonder Messrs. Howe and Sauveur were able, with what may be termed "minute" samples (only about ¼ inch area and quenched in brine at comparatively low temperatures, namely from 1200° F. to 1600° F.) to obtain high breaking loads.

The Terre-Noire Company, in their famous set of test-bars exhibited at Paris in 1878, were able by varying the manganese percentage to obtain the following results:—

Terre-Noire Samples.

No. of Sample.	26	33	30	21
Carbon	0·45	0·46	0·51	0·56
Manganese	0·52	1·06	1·30	2·00
Raw forged steel. { Elastic limit	17 tons	23 tons	28 tons	31 tons
Breaking load	34 tons	41 tons	52 tons	57 tons
Elongation	24 per cent.	21 per cent.	15 per cent.	9 per cent.
Oil-tempered. { Elastic limit	30 tons	44 tons	} Cracked in tempering	Cracked in tempering
Breaking load	48 tons	82 tons		
Elongation	14 per cent.	Broke		

These experiments were very conclusive as to the powerful action of manganese, the carbons in these samples varying but little.   There was no doubt that manganese, up to at any rate several per cents., acted in a similar manner to chromium and tungsten, and as a sort of whip to urge on the lazy carbon—that was, lazy in its lower percentages—to its duty of combining with the iron in the form of a carbide of iron or a double carbide of iron and manganese.

He then referred to 274 of Paper I. as another proof of the untenability of the authors' position.   They quoted a specimen of Mr. André le Chatelier's steel in proof of their case, and that that sample (thin wire, it should be remembered) contained " far too little carbon to explain the increased tenacity referred to."   But when they came to look into the question they found, as a matter of fact, the sample did contain as much as 0·06 per cent. carbon—not at all a negligible quantity if further elements were present. In the first place, 0·06 per cent. is very low for commercial steel. While, of course, he was in no way questioning the analysis, he should like to point out that it was not stated whether that was from a colour or combustion test; if the former, it would certainly only be approximate.   But what said Mr. le Chatelier himself in a letter dated September 3, 1895 ?—" I have not the full analysis of the wire in question, and only know that it contained 0·40 per cent. manganese, and I am fully convinced that it is owing to this manganese that it hardened so much by *la trempe*."   He was entirely in agreement with Mr. André le Chatelier, and this evidence had been further confirmed by the remarkable experiments of Mr. Charpy presented to the Société d'Encouragement pour l'Industrie Nationale in 1895 regarding the influence of manganese and chromium upon iron.

If, therefore, 0·4 per cent. manganese in combination with 0·06 per cent. carbon had so powerful an effect, what must 1·19 per cent. manganese have upon the steel (containing 0·21 per cent. carbon) selected by the authors as a basis for their experiments, and selected, so he gathered, as a representative specimen of the properties of 0·21 per cent. carbon steel, which it certainly was not.   The manganese present must have had very considerable influence, and he was specially glad to see his belief so strongly supported by the further interesting series of tests then exhibited by Professor Arnold.

Speaking for one moment of the great influences of small quantities or traces of elements upon the metal (iron), this Institute was greatly indebted to Professor Roberts-Austen for the admirable work he had done in that direction, and no one had more strongly brought that matter to a clear and practical conclusion. Therefore, when considering such exceedingly fine lines of distinction as were under discussion in the present papers, and upon which were based theories of the utmost and most vital importance to the metallurgical world, special consideration must be paid to that important point, and due weight given to its influence.

Let it be remembered how jealously minute variations in analyses were watched at that time, differences of as little as 0·02 per cent. The whole of Sheffield's high-class tool steel trade was chiefly based upon differences in the material of only 0·02 to 0·03 per cent., for example, of phosphorus. In other words, 0·02 or 0·03 per cent. might represent high quality, whereas 0·05 or 0·06 per cent. would not be suitable, not exactly inferior, but at any rate unsuitable for certain special purposes.

Then again, they knew that carbon, as compared with other elements, had by far the most powerful influence upon iron, more so than even sulphur or phosphorus, and was it not really a mistake to formulate important theories without recognising those now well-admitted facts ?

He should like to refer to some experiments of his own made some time ago, the results of which seemed to him to entirely conflict with the authors' results. That was in 1891, or five years ago, when he tested the very same point upon which the authors laid so much stress, viz., the possibility of increasing the tenacity of iron containing very little carbon. He would leave members to judge as to which set of experiments more nearly answered the object which both the authors and he had in view.

First, as to the authors. They selected sections of very small area, the steel containing 0·09 per cent. carbon. It is well known that such a percentage might have quite a considerable effect (though they termed the material " practically carbonless "), specially when it was considered the pieces were dipped in a freezing mixture from a temperature of 1650° to 1800° F. Such treatment would not only cause a certain amount of hardening, in

fact as much as could probably occur from the presence of 0·09 per cent. of carbon, but would also produce a certain amount of sur-face rigidity—" surface tension," as Professor Roberts-Austen aptly terms it—and in his opinion it was readily possible to account for the increased tensile strength without having to bring to their aid hypotheses or theories.   The facts were there, and offered quite sufficient explanation in themselves.   Besides, too, they did not know what other elements were present in the authors' basic steel samples.   It was possible there would be at least 0·40 per cent. of manganese, and in face of Mr. André le Chatelier's statement it might be expected that increased tensile strengths would naturally result from that element.

Then his own examples, shown to the Iron and Steel Institute in May 1891, were made from Swedish bar iron con-taining 0·07 per cent. carbon with 99·80 per cent. of iron.   He submitted the test-bars, which had nearly double the area of the authors' samples, to a treatment similar to that used in the American tests.   The following were the results :—

Sample No.	Treatment.	Tensile Strength in Tons.
		Per sq. in.
7	Heated to yellow heat, quenched in water (60° F.), and reheated to yellow heat	17·90
4	Welding heat, cooled in air	19·05
8	Yellow heat, cooled in water, and reheated to low red .	20·82
5	Yellow heat, and cooled in air	20·94
3	Low red, and quenched in water	21·22
2	Yellow, and quenched in water	21·28
1	Welding, and quenched in water	21·55
6	Tested just as forged, evidently " hammer-hardened " .	22·58

The tests were in this case made for him by an independent observer, Professor Ripper, the Principal of the Sheffield Technical School.   The testing-machine used was a Wicksteed-Buckton of the latest type.

Disregarding the abnormal sample No. 7, the increase in tenacity obtained was under 20 per cent., or, including No. 7, about 28 per cent.   It was curious to note, too, that the highest stress was obtained from the bar tested just as forged ; no doubt it had been " hammer-hardened."   This sample, so it seemed to him, was a clear proof that the increases in tenacity obtained were chiefly due rather to surface tension than to other causes.
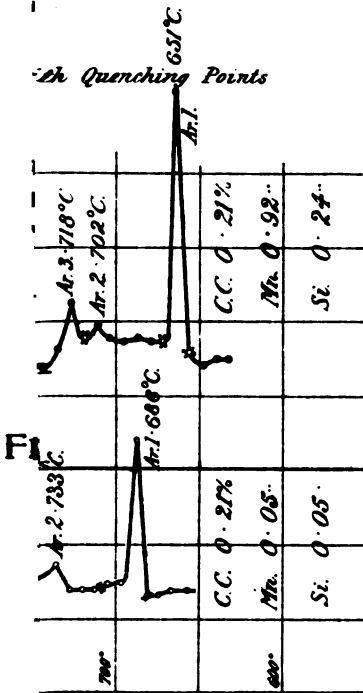
PLATE IX.   193

FIG. 4.

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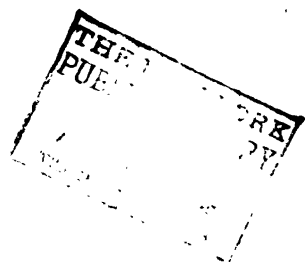
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This matter of surface tension being so important, and in face of the paper by Mr. Howe, presented to the Institute at the Birmingham meeting, in which he raised such exceedingly important considerations, he intended to make a further bar for this series and have it quenched, then machined to remove the surface tension induced by sudden cooling. He thought it was probable the result would show but little gain in tenacity.

It would be noticed that the following table of further experiments made this year almost entirely confirmed those of 1891, the greatest increase in tenacity being but little over 25 per cent. The notes accompanying the table gave full information respecting several of the interesting results obtained.

In 1891 Professor Roberts-Austen, representing believers in allotropy, stated when commenting upon the remarks which he then made in connection with the samples just referred to—that was at the reading of Dr. Ball's paper in May 1891—that his (Mr. R. A. Hadfield's) series of tests proved his (Professor Roberts-Austen's) case, because the material was not raised in tenacity, and that " unless a certain amount of carbon was present the Beta or hard molecular grouping could not be retained."

But Messrs. Howe and Sauveur said very decisively that " the allotropic theory has had one of its strongest supporters in the fact that almost carbonless iron undergoes great strengthening on quenching." And he gathered from their papers that they believed it was probable that that strengthening was due to some allotropic modification of the iron present. If, therefore, Professor Roberts-Austen's statement stood, then, so it seemed to him, Messrs. Howe and Sauveur's certainly fell to the ground, or *vice versâ*.

As a matter of fact, was it not unsafe to generalise or base any important law upon small specimens of very low carbon material ?

Besides, too, in such samples there was a fictitious or strained condition, partly misnamed hardness, in which probably neither chemical nor molecular change of condition really played any great part, or at any rate acted only upon the surface skin, and certainly could not be considered a satisfactory basis for founding laws of such vast importance as would entirely alter the conceptions they have hitherto had of the structure of iron and steel.

1896.—i.   N

Experiment 3695, on Swedish Bar Iron containing 99·80 per cent. Fe.

Drillings taken from	Bar.	Bar.	End of test-bar No. 1978 F.	End of test-bar No. 1979 F.	End of test-bar No. 1980 F.
Carbon.	·04 to ·07 comb.	·04 to ·07 comb.	·03 % comb.	·02 % comb.	·04 % comb.
No. of test-bar.	1976 F.	1977 F.	1978 F.	1979 F.	1890 F.
Cut from	Flat bar 3″ wide × ⅝″ thick.	Flat bar, 3″ wide × ⅝″ thick.	Flat bar, 3″ wide × ⅝″ thick.	Flat bar, 3″ wide × ⅝″ thick.	Flat bar, 3″ wide × ⅝″ thick.
Treatment.	Machined out of iron as received. No treatment.	Heated to yellow heat, and quenched in cold water about 60° F.	Annealed by malleable iron process. No further treatment.	Annealed by malleable iron process, heated to yellow, and quenched in cold water about 60° F.	Annealed by malleable iron process, and outside skin machined off after annealing. No other treatment.
Transverse or Longitudinal.	Longitudinal.	Longitudinal.	Longitudinal.	Longitudinal.	Longitudinal.
Size of bar, all tested on 4″ lengths.	¾″ × ½″	¾″ × ½″	¾″ × ½″	¾″ × ½″	¾″ × ½″
Area.	0·3728 sq. in.	0·3749 sq. in.	0·3559 sq. in.	0·373 sq. in.	
Permanent set in tons, per sq. in.	11·72	11·10	9·12	16·75	9·40
Amount of extension at perm. set.	0·0132	0·0067	0·011	0·0094	0·0065
Breaking load in tons per sq. in.	22·11	24·66	20·36	27·48	Taken out at 15¼ tons.
Elongation % on 4″.	31·00	22·50	35·50	22·75	Test not completed owing to the threads of the test-bar giving way at 15¼ tons.
Reduction in area %.	52·27	60·05	71·98	55·33	
Fracture.	Fibrous— 1″ adjacent to fracture elongated 59 %.	Fibrous— 1″ adjacent to fracture elongated 48%.	Fibrous— 1″ adjacent to fracture elongated 63 %.	Fibrous— 1″ adjacent to fracture elongated 52 %.	

NOTE 1.—The following is the sketch of test-bar :—
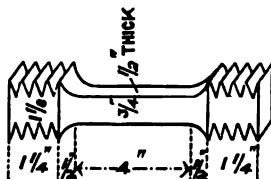
NOTE 2.—As regards the analyses, the whole of the carbons are by combustion, but it must not be forgotten that these small percentages are subject to error, and, speaking generally, specially as regards samples 1978 and 1979, which are analyses taken from the outside of the bar, they hardly represent the average percentage of carbon. I do not believe these would be less than 0·05 per cent. throughout the whole of the bar.

NOTE 3.—1980 F bar. Unfortunately the threads stripped during the test, but as the set point has been obtained, this being low, it is probable the breaking load would not have been higher than about 21 tons per square inch, as in the case of specimen 1978 F.

He claimed that his own specimens, both in the experiments of 1891 and the further recent ones described, seemed more likely to teach the truth, for they were far nearer to the ideal specimens required to test the queries raised by Mr. Howe, that was, they were nearer to carbonless iron than he believed had before been obtained.

In conclusion upon that side of the question, he might say that whatever increased tenacity had been obtained in the various samples, that was probably owing to a number of circumstances which would have to be taken into account as regards experiments of that kind. A portion might be due to carbon changes, others to the strained condition induced by the sudden quenching, some carbon might have been taken up on the exterior of the bar during the heating of the samples as suggested by Mr. Stead. But in any case the increases obtained were so small as to clearly prove that those referred to by Messrs. Howe and Sauveur must have been of an entirely different character, and upon samples certainly not containing anything like 99·80 per cent. iron, and consequently not sufficiently free from " influencing or determining elements " as to be really of service, or a basis for the formulation of such important new theories as had been put forward for consideration.

There was only one other point in Mr. Howe's first paper (p. 274) to which he would refer. He had had the pleasure of showing to this Institute about two years ago a specimen of manganese steel, one part of which was magnetic, and the other part, though on the same bar, non-magnetic. But the allotropists had claimed that manganese steel was non-magnetic and hard, because it contained a hard allotropic form of iron called Beta iron, which, it was believed, was hard and non-magnetic. But in the face of that sample of magnetic and non-magnetic steel on the same bar, it had not seemed possible to him that such a theory could be maintained, nor did he see any reason to change the opinion expressed two years ago as to what he believed was the real cause of the change, viz., a change in carbide condition, a belief which was so strongly shared and confirmed by his friend Mr. Stead.

But that was not all. Naturally, if Beta iron was hard and non-magnetic, why was not hard carbon steel non-magnetic ?

As a matter of fact it was so magnetic that not only could it be highly saturated with magnetism, but under certain conditions it could be made to retain more magnetism than any other steel. Yet they were told, and that seemed to him a very weak part of the case, that the magnetic properties of hardened carbon steel must have been owing to the presence of some soft or Alpha iron. Thus a magnet of glass-hardened carbon steel was hard because of the hard and non-magnetic Beta iron, but was magnetic because of the soft Alpha iron present. Could there be a greater contradiction of terms?

If Alpha, or soft, iron could exist in such a sample of hardened steel, evidence of its presence must have been before detected in the most minute researches made by various chemists and microscopists. There was no one, since Dr. Sorby's great work, who had so minutely examined and read the structure of steel as Professor Arnold, who, be it remembered, had gone up to 800 diameters; and although he had not before referred to that point with him, he would like to ask him publicly if, in his opinion, there was the slightest ground for such a statement that there was soft or Alpha iron present in a glass-hardened steel specimen, say 1 inch diameter and containing 1 per cent. of carbon. Neither physical, mechanical, nor chemical research offered or suggested such an explanation. In a bar of the size he had just mentioned the hardness was uniform throughout, and no matter how small a quantity of the so-called Alpha iron might be present, he felt convinced that it would have been possible to detect it by tests such as those referred to. Besides, too, the harder the steel was quenched the more Beta non-magnetic iron should be present according to the statements of the allotropists; but that was not so (the harder the steel the more suited was it for magnetic purposes), and yet that was one of the facts which it was stated in the papers was suggestive of allotropic modifications of iron.

According to the explanations offered, in all our cutting and edge tools, or our razors, the hardened magnetic portion holds also the soft Alpha iron. He would leave members of that Institute to draw their own conclusions as to the strength of such a theory.

But there was still one other aspect of that part of the subject to which he would like to refer.

He thought that it was not yet sufficiently recognised how extraordinarily sensitive to change was the hardening carbide of iron, termed by Professor Arnold "sub-carbide," a point which was so ably brought out by him in his recent paper to the Institution of Civil Engineers. Those changes occured far below the points at which claims were made that they could be due to change in condition of the iron; in other words, to formation of Beta iron. Professor Arnold found that the changes commenced at even as low a temperature as 100° C., a fact which had been very strikingly proved by his friend Professor Barrett, F.R.S. So far back as December 1889, in a paper read before the Royal Dublin Society on " The Magnetic Moment of Steel," he stated :—

" The very high coercive force of manganese steel rendered it interesting to ascertain the effect of increasing temperature on its magnetic moment. Accordingly the portion of No. 552, which had not been annealed, was magnetised in a powerful field, and having been placed in an oil bath at a fixed distance from the magnetometer, it was gradually raised in temperature, and the magnetometer deflections noted every 10° C. up to 250° C. ; a similar series of observations were made during the cooling of the bar. For the sake of comparison, a bar of ordinary magnet steel was magnetised in the same field, and then submitted to a similar heating and cooling. The result was that the magnetic moment per gramme of the manganese steel fell from 0·14 at 18° C. down to 0·082 at 250° C. ; or a fall of 40 per cent., and in cooling back to the temperature of the air it rose to 0·111. The ordinary steel magnet, on the other hand, had a moment per gramme of 14·1 at 18° C., and it fell to 1·75 at 250° C., or a fall of 87 per cent. ; in cooling back to the air it regained a moment of 6·5. In the accompanying diagram the moments per gramme are plotted against the corresponding temperatures. In order to bring the manganese steel in the same diagram, its vertical scale had been multiplied 100 times. The dotted line in each case shows the magnetic moment regained in cooling. It will be noticed that the permanent magnetic loss by heating to 250° and then cooling is much greater with ordinary than with manganese steel."

It seemed to him those were very striking facts, and proved, as

Professor Arnold had also stated, that the changes in the carbon condition were very subtle indeed, and even now but little understood.
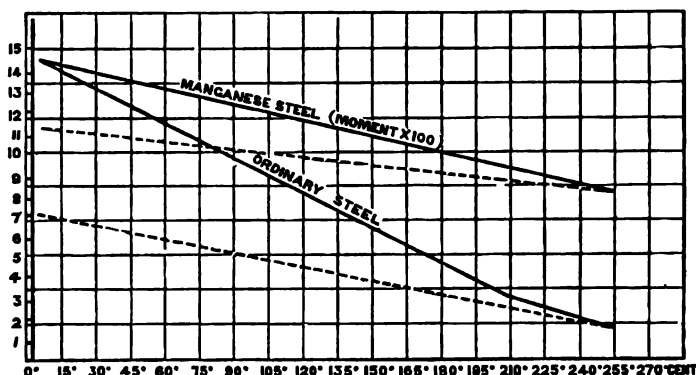
Continuing, Mr. Hadfield said that Mr. Osmond, in his interesting communication, referred to some samples of steel containing $3\frac{1}{2}$ per cent. of manganese which he (the speaker) had sent him. He stated that No. 311 sample, although containing 1·00 per cent. carbon, cooled by him, was quite soft; but in the first place he (the speaker) had recently treated a specimen from the same bar in a similar manner and found it exceedingly hard and capable of scratching glass. His sample must, therefore, have been cooled in some different manner, probably too slowly, which would readily account for the difference. But apart from that, he (the speaker) would remind him that the fact of that specimen, No. 311, with much higher carbon than No. 309 (0·33 per cent. C.), which he stated did possess glass-scratching hardness, becoming soft had very little to do with the case, for spiegeleisen with about the same percentage of manganese, but containing four to five times the quantity of carbon, was always intensely hard. What he had been desirous to prove in the other samples to which he (Mr. Osmond) referred, that was, steel with $3\frac{1}{2}$ per cent. manganese but with only 0·10 per cent. carbon, was that as soon as the carbon got down to this low limit, it was then impossible by any treatment to give it glass-scratching hardness. To make the matter perfectly clear he would recapitulate the experiments.

Sample No. 309, containing 0·33 per cent. of carbon and 3·67 per cent. of manganese, sent several years ago to Mr. Osmond, was intensely hard in the cast or forged form if quickly cooled, in fact, so hard that it would readily scratch glass, and so weak in structure that it could be pounded into powder without any great difficulty ; it was in fact not nearly so strong as ordinary cast iron. He was inclined to think, too, that the carbon was not so low as 0·33 per cent. ; that analysis was made by the colour test, and was, therefore, not absolutely sure. It would probably be found by the combustion test to be nearer 0·45 per cent. He much regretted this error, if such it should be.

No. 311 contained 1·00 per cent. of carbon, 3·76 per cent. of manganese. Mr. Osmond stated that he cooled that sample down in a similar manner to the preceding specimen, and it was quite easily filed. He himself felt confident that there must have been some difference in the rate of cooling, for both the foregoing if cooled quickly, that was not in any way annealed, must have been intensely hard. He had repeated the experiment many times, and always with the same result. He thought it would be admitted it was hardly probable that *more* carbon would give a softer product; he did not therefore see the strength of Mr. Osmond's argument, or as to how it bore upon the points under consideration. Both the materials above mentioned, if cooled slowly or annealed, could be readily machined, but as cast in the ordinary manner, say in iron ingot moulds, 2½ inches to 3 inches square, or forged into bars and cooled in the open air, they were invariably intensely brittle and hard.

He had naturally been long anxious to obtain the same alloys as above, but with the carbon absent or nearly so, but it was only recently that this had become possible. He had now produced an alloy, No. 1379/B2, containing almost the same manganese as the specimens before named, viz., 3·48 per cent., and with the carbon as low as 0·07 per cent. (combustion). What was the result ? The product could be readily drilled and filed either in its cast or forged condition. No matter what the heat treatment to which it might be subjected or how quickly quenched, it invariably remained soft in the ordinary sense of the term. In its forged condition it could be easily machined into test-bars, and then had a breaking strength of 66 tons per

square inch, with an elongation of $7\frac{1}{2}$ per cent. upon 2 inches.
As might be expected, the comparatively large percentage of
manganese considerably stiffened the material, exactly as was the
case with Professor Arnold's sample containing 1·80 per cent.
manganese and 0·08 per cent. carbon.   It must not be forgotten
that they now had the metal manganese readily available in the
metallic form, and one of its properties was extreme hardness.   One
could therefore understand the presence of so large an amount as
$3\frac{1}{2}$ per cent. of this element would readily account for the increased
stiffness.   He hoped to have before long a complete series of
manganese alloys in which the carbon was practically absent, or
present in only very small percentages.   So far his experiments
most clearly proved that there again it was to carbon that they
owed the hardness, or in its absence the lack of it.

In conclusion, therefore, he must differ from the conclusions
of the authors of the three communications.   They had laboured
hard and long for their cause, and every credit was willingly
given to their investigations.   If they, their opponents, were
wrong in their conclusions they would willingly admit the error
of their ways, but certainly no fresh facts had yet come to light
to warrant such an alteration of opinion.

Professor J. O. ARNOLD had studied Mr. Howe's paper with
great interest, and since its publication six months ago he had
also carefully gone over the ground covered, experimentally.   The
paper was chiefly theoretical, and the conclusions arrived at were
based upon experimental data, occupying only a single page.   The
theoretical portion of the paper was well worth studying, because
it presented to the student a model of thoughtful and often judicial
argument.   Before dealing with the practical portion of the paper,
the speaker would endeavour, in response to several requests, to
arrive at an agreement with reference to the definition of allotropy.
He believed that the views of Professor Roberts-Austen and him-
self did not widely diverge.   In the first place, he pointed out a
change such as that from water to ice was generally admitted to
be due, not to allotropy, but to the phenomenon of congelation,
otherwise, if changes of form in matter due to temperature were
to be called allotropic, then melted butter became an allotropic
modification of ordinary butter.   There were, he said, many well-

marked instances of allotropy in solid bodies, such as the case of red and yellow phosphorus, but hitherto it had not been possible to determine their comparative molecular configurations. There was, however, a gaseous element presenting a well-marked case of allotropy, namely, oxygen, and with the molecular configuration of its two forms chemists were well acquainted. Ordinary oxygen constituted 20 per cent. of inhaled air: ozone, under similar conditions, would act as a deadly poison. The molecules of oxygen and of ozone are of the same dimensions, but the molecule of oxygen contains two atoms only, but in that of ozone are concentrated three such atoms. This case Professor Arnold adopted as the type of allotropy.

Mr. Howe had concluded his paper with a theory called the carbo-allotropic theory, which, the speaker said, if the data upon which it was founded were sound, would startle the pure chemical world. Mr. Howe urged that an element may preserve its allotropic identity after combination with another element, to form a compound. To carry out this idea to a logical but absurd conclusion, it might be urged that the non-poisonous properties of CO_2 were due to the fact that in it the oxygen existed in its diatomic form, whilst the actively poisonous properties of CO were due to triatomic oxygen. Professor Arnold looked on Mr. Howe's paper as a laudable effort to induce the two schools of metallurgists to accept a compromise, but this seemed impossible. The hardening constituent of steel was either an allotropic modification of iron or it was an attenuated carbide of iron; but the existence of an attenuated carbide of an allotropic modification of iron was a theory opposed to all known chemical laws, and was not supported by any experimental evidence. Professor Arnold considered that the practical portion of Mr. Howe's paper was admirable up to a certain point, though the tremulous nature of the recalescence curve suggested that his pyrometric or recording apparatus was by no means perfect, the more so because the excessively long intervals employed would tend to mitigate slightly uneven furnace radiation. Broadly, Mr. Howe had taken a steel containing 0·21 per cent. of carbon to ascertain its tenacity when suddenly quenched in the form of small bars from various temperatures in cold brine.

From the relations existing between the tenacities and quench-
ing temperatures, Mr. Howe had deduced a new and startling
theory.   It might seem at first sight that 0·21 was not a suitable
percentage of carbon upon which to determine the hardening pro-
perties of steel, nevertheless Mr. Howe's selection of this quantity
was theoretically and practically sound, because only in iron
containing about this amount of carbon were the three critical
points Ars$_1$, $_2$, $_3$ distinct and non-confounded.   For Mr. Howe's
purpose it was absolutely necessary that these points be isolated,
in order to accurately measure the changes in tenacity resulting
from the quenching of the steel immediately above or below the
critical ranges.   Mr. Howe's specific object was to ascertain the
exact influence of carbon on the hardening of iron, and it would
have seemed to the speaker that the simplest scientific precaution
would have induced Mr. Howe to have employed for his ex-
periments a nearly pure iron and carbon steel, but from some
oversight, quite inexplicable in the case of an experienced steel
metallurgist, Mr. Howe actually selected a material containing
eight times more impurity than carbon, including no less than 1·2
per cent. of manganese and 0·3 per cent. of silicon.   Mr. Howe
having by a series of skilfully carried out experiments obtained
a set of results from this material, he founded upon them an
elaborate theory of the hardening of steel on the basis that his
iron contained only carbon, or that the manganese and silicon
present would not influence the tenacities of the quenched bars.
    The impurities present in Mr. Howe's steel had produced a
thermal curve very different from that obtained with nearly pure
iron containing 0·21 per cent. of carbon.   Fig. 1 (Plate IX.) repre-
sented the recalescence curve obtained from a steel containing 0·21
per cent. of carbon, 0·05 per cent. of manganese, and 0·047 per cent.
of silicon, cooled from an initial temperature of 967° C.   Fig. 2
represented Mr. Howe's curve, the intervals and rates of cooling of
the two steels being practically identical.   It would be seen that
in Mr. Howe's curve the critical points Ars$_3$, $_2$, instead of being
separate, are confounded, so as to render it impossible to quench a
sample between them.   The carbon point Ar$_1$ was also 80° below
its normal position, and the heat evolved at this point was at least
50 per cent. greater than that evolved from nearly pure iron con-

taining 0·21 per cent. of carbon. Not only had impurities in Mr. Howe's sample lowered the carbon change point 80° from its normal position in true carbon steels; but the contour of the curve clearly showed that a portion of the carbon was changing its condition from Ar_3 downwards long before the change acquired its maximum velocity at Ar_1. The huge difference existing between the recalescence curves was reflected in the mechanical tests made by Professor Arnold. The pure 0·21 carbon steel was reduced to bars of the exact size employed by Mr. Howe; the bars were hardened under exactly the same conditions as Mr. Howe's; each from its own recalescence curve at the temperatures indicated by the crosses on the curve, the nearest corresponding points of Mr. Howe's series being also marked on his curve. The comparative tensile results were set forth in Table I.

TABLE I.

Carbon 0·21, Mn 1·19, Si 0·31.			Carbon 0·21, Mn 0·05, Si 0·05.			Error Due to Mn and Si. Tons per Square Inch.
Quenching		Tons per Sq. Inch.	Quenching		Tons per Sq. Inch.	
Point.	Temperature.		Point.	Temperature.		
	Deg. C.			Deg. C.		
Above Ar_3 .	733	98·6	Above Ar_3 .	790	33·4	65·2
Above Ar_2 .	698	92·2	Above Ar_2 .	758	34·7	57·5
Above Ar_1 .	650	63·3	Above Ar_1 .	687	31·7	31·6
Below Ar_1 .	575	41·6	Below Ar_1 .	662	28·7	12·9
Normal . .	20	33·0	Normal . .	15	24·5	8·5

It would be seen that a pure 0·21 per cent. carbon steel gives in its normal condition a stress, not of 33, but of 24 tons per square inch; also that the change at Ar_3 did not appreciably affect the tenacity of the metal, whilst the changes at $Ars_{1, 2}$ produce falls of 3 tons in the stress. It will also be seen that the maximum increase in hardness, due to quenching iron containing 0·21 per cent. of carbon, was not, as stated by Mr. Howe, 65 tons per square inch, but only 10 tons. The actual maximum stress was not 99 tons per square inch, but 35 tons. The speaker therefore concluded that Mr. Howe, in proposing a new theory involving the most delicate points in the molecular physics of steel, had

founded his deductions upon an initial mechanical error of 65 tons
per square inch. In order still further to prove the matter, Pro-
fessor Arnold had prepared an ingot containing less impurity than
Mr. Howe's, containing carbon 0·21, manganese 0·92, silicon 0·24.
The results obtained on submitting quenched samples 0·564 in. in
diameter and 1·12 in. long to a uniform compression test of 50
tons per square inch, are set forth in Table II.

TABLE II.

Carbon 0·21, Mn 0·92, Si 0·24.		Compression per Cent., 50 Tons per Sq. Inch.	Carbon 0·21, Mn 0·05, Si 0·05.		Compression per Cent., 50 Tons per Sq. Inch.	Difference Due to Si and Mn. Compression per Cent.
Quenching			Quenching			
Point.	Tempera-ture.		Point.	Tempera-ture.		
	Deg. C.			Deg. C.		
Above Ar_3 .	733	0·97	Above Ar_3 .	784	17·37	16·40
Above Ar_2 .	698	0·53	Above Ar_2 .	766	17·72	17·19
Above Ar_1 .	661	1·24	Above Ar_1 .	698	18·18	16·94
Below Ar_1 .	645	8·80	Below Ar_1 .	680	22·54	13·74
Normal . .	15	12·30	Normal . .	15	29·91	17·61

It would be observed that the points $Ars_{2, 3}$ had not affected
the hardness of the steel to any appreciable extent; also that the
change point Ar_1 was accompanied by a marked softening effect.
Above Ar_1 the average compression was in the impure metal only
about 1 per cent., but in the pure metal about 17½ per cent., thus
very clearly showing the remarkable hardening influence of the
manganese and silicon.

This influence was shown graphically in Fig. 3, in which the thin
line at the top was zero. The double lines showed the crushing
pieces of the iron and carbon steel, and the full thick lines the
carbon-manganese-silicon steel after compression. In spite of the
opinion of Professor Roberts-Austen to the contrary, Professor
Arnold still held that the hardness of steel was much more
accurately measured by compression than by tension, the effects
of structure interfering with the truth of the results obtained by
the method last named. The recalescence curves were plotted in
Fig 4. He wished to put in a plea for the micrographic analysis
of steel which was coming to the fore, and which steelmakers

would have to deal with, because engineers had taken the matter into their own hands, and would force steelmakers to use it. Already that science, which would be of the utmost importance, was threatened with a grave danger, viz., the danger of introducing synonyms into its nomenclature. He thought that pioneers in research like Mr. Howe and Mr. Osmond should be very careful in their nomenclature, and should try not to confuse the student. They should remember that students were not made for them, but that they were made for the students. They had already two sorbites. They had also hardenite (which was a sub-carbide) and martensite, all meaning the same thing; and unless they took some little trouble to ascertain the views of other micro-scopists in Great Britain, the whole of the science would be in such confusion with its nomenclature that its progress would be seriously impeded.

Names prematurely given to constituents, the very existence of which was doubtful, could not be generally accepted. The matter would eventually have to be settled by an international conference of steel microscopists, and it was certain that English metallurgists would insist that the name of Dr. Sorby, the founder of the science, should be associated with an important and not with an obscure constituent.

In view of Mr. Hadfield's experiments on pure Swedish iron, and of his own on 99·88 per cent. molten iron, it seemed evident that pure "carbonless" iron could not be appreciably hardened by quenching. If, however, Mr. Howe was still unconvinced, he could supply him with 3-inch ingots of 50 lbs. weight, or rolled bars containing 99·9 per cent. of iron, 0·03 per cent. of carbon, and a trace of manganese, to carry out his tests. Mr. Howe's statement that he was prepared to admit that any metal stressed beyond its elastic limit assumed an allotropic form was, he thought, hardly intended to be taken seriously.

Mr. Howe's research, taken in conjunction with his own, con-stituted strong proof of the accuracy of the theory that the varying properties of steel were due to attenuated compounds of iron, and not to allotropic modifications of that metal. It was clear, he said, that 1·19 per cent. of manganese or 0·31 per cent. of silicon added to pure iron would produce in the quenched metal a compara-

tively insignificant increase in tenacity. Even the effect of 0·21 per cent. of carbon was not very great, but a combination of these quantities of the three elements produced in the iron containing them, as had been clearly shown by Mr. Howe, the enormous tenacity of 100 tons per square inch.

In conclusion, he would point out that the general position of the allotropists was somewhat curious. Mr. Osmond it seemed, from his remarks on Mr. Howe's paper, still held that the allotropy of iron was governed by the periodic law. This theory was now almost universally discredited by steel metallurgists, and certainly by Mr. Howe. It was held by Mr. Osmond that the carbon in steel above 700° C., or in the quenched metal, was in solution; Mr. Howe held that it was in strong combination with the iron; and Professor Roberts-Austen entirely agreed with Mr. Osmond's views, and was in strong sympathy with Mr. Howe's.

Until the allotropists really had some clear and definite theory to advance, it seemed waste of time and energy to continue the controversy.

Mr. J. E. STEAD said that controversies of this kind did not always get at the truth, but he was perfectly sure that this most interesting controversy would eventually land them into the whole truth in connection with the matter. There was one thing only that he ought to refer to as there was not time for him to discuss the papers fully, that was the question whether the carbon was in a state of carbide in hard steel, or whether it was in a dissolved free state. If they had had the pleasure of hearing Mr. de Benneville's paper, they would find that that gentleman discussed that question, and came to the same conclusion that every chemist who had studied the matter must have come to, namely, that the carbon must be in combination with the iron in some form or other, in hardened steel, for the reason that when hardened steel, no matter how hardened, was treated with either sulphuric acid or hydrochloric acid, the whole of the carbon came off as a hydrocarbon. If that carbon was only free carbon dissolved in the iron, it would be left insoluble as a black residue, and they could not conceive of such a thing as free carbon in iron, or in hardened steel combining with hydrogen and forming

a hydrocarbon. Therefore, they must abandon the idea of dissolved carbon, and conclude that it must exist as some carbide or as carbide of iron.

Mr. THOMAS WRIGHTSON had heard with interest Professor Arnold's description of his view of allotropy. He had always understood that an allotropic change was a change in the substance, which, without affecting its chemical constitution, produced different physical properties. Although they might not in inorganic chemistry have any experience of an allotropic modification which would form compounds different in a chemical sense from those which could be formed by the substance in its normal state, yet it was well known that an allotropic modification of an element would combine more or less readily with another element than the element in its normal state would. With regard to the physical side of the question, it did not appear altogether unreasonable to suppose that if a substance had passed through an allotropic change, by which the material was not in its properties the same as before, it would combine with other substances with a physical effect different to the combination with the material in its original condition. It appeared to him that these problems of hardening steel must necessarily take account of allotropic changes in iron, if he was right in this view. Iron and carbon were both elementary substances, and each could exist in various allotropic forms. If we took the purest commercial iron they found that its physical properties underwent remarkable changes under variations of pressure and temperature. The change indicated by the well-known recalescent point was one which had been connected with phenomena of hardening by Mr. Osmond and Professor Roberts-Austen. Another remarkable allotropic condition to which he (Mr. Wrightson) had given special attention was that which coincided with the range of temperature at which iron could be welded.* Within this limited range the iron assumed some properties which were entirely different to the properties of the iron at a lower or higher temperature.

Outside this limited range iron followed the ordinary laws of other materials; it expanded with increase of heat and contracted with a diminution of heat; whereas within the welding range of

* *Philosophical Transactions of the Royal Society*, vol. clxxxvi. pp. 593–602.

temperature the material acted exactly in the opposite way, viz., it contracted by increase of heat and expanded by decrease of heat, and hammering or pressure of the material when in this remarkable allotropic form had the effect of cooling instead of heating. A substance could only be defined by its peculiar properties. If a change took place in these properties it was not the same substance, although when the difference was small or little known, it might be called by the same name through our ignorance or for simplicity of nomenclature. His view of the allotropic argument was that it was perfectly reasonable to suppose that if carbon combined with iron at a given temperature the physical result might be one thing, but that if the carbon combined with the iron at a time when the physical properties of the iron had become altered the physical result might and probably would be something quite different, although we had no evidence of chemical change; and as carbon and iron were both subject to several allotropic changes, the physical combinations might probably be of a most varied character. After all, the chemist could only tell them the chemical constituents of any substance after it had been subjected to treatments in his laboratory, which entirely altered its original physical condition, and as that original condition was what they wanted to know all about, the methods of the chemist must be supplemented by the methods of the physicist if it were desired to arrive at the truth.

CORRESPONDENCE.

Dr. JOHN HOPKINSON, F.R.S., noted that in Mr. Osmond's paper reference was made to the alloys of iron and nickel. He wished to point out that he had investigated* these alloys several years ago. The properties of the alloy with 20 to 25 per cent. of nickel were very remarkable. As the material came from the maker it was non-magnetic, but if it were cooled to 50° C., the character of the material entirely changed; it became magnetic, and on warming remained magnetic till the temperature was raised to about 700° C. It then suddenly changed to the non-magnetic

* *Proceedings of the Royal Society*, vol. xlvii. pp. 23 and 138, vol. l., June 3, 1891, vol. xlviii. April 17, 1890.

condition. Thus at any temperature between something below freezing and 700° C., this material existed in two different conditions. The conditions differed not only in magnetic properties, but in many other respects. Non-magnetic nickel steel had a density of 8·15, whilst that of magnetic nickel was 7·98. The electric resistances differed 40 per cent. The tensile strength of the magnetic variety was about 80 tons per square inch, whilst that of the non-magnetic variety was 50 tons per square inch.

Mr. F. OSMOND pointed out that in a separate paper he had already expressed his views on the remarkable researches of Mr. Howe on the hardening of steel, so that the following observations were confined more particularly to the supplementary paper by Mr. Howe and Mr. Sauveur. He agreed with the authors in their micrographic observations, and only intended to discuss the question whether the ordinary definition of tenacity did not lead to an apparent complication in the general conclusions drawn from the results of thermal, micrographic, and mechanical tests.

According to the almost universal custom, *tenacity* was considered as the maximum load supported by a test piece divided by its original section, but it was nearly always forgotten that this maximum load, for metals susceptible of deformation, was applied in fact to a reduced section. The quotient obtained was thus less, and often very much less than the load which was really sustained at a given moment by unit of actual section. If, on the contrary, as had sometimes been proposed, the measure of tenacity were taken as the quotient of the maximum load by the section at rupture, the figures obtained were too high, as the load carried at that instant was lower than the maximum. Probably it would be better to consider together the load really supported at the moment of rupture, and the corresponding section, that is the broken section, and this might be called the *absolute tenacity*.

In this manner Mr. Considère had found the following figures for a very mild steel :—

		Kilogrammes.
Relative tenacity = maximum load . .	{ per square millimetre of original section . . . }	40·3
	{ per square millimetre of the section at fracture . . }	93·6
Absolute tenacity		71·6

Unfortunately most testing-machines did not show the load really supported at the moment of fracture, and even when they could do so, it was but seldom that it was recorded. Mr. Howe's results conformed to the general practice on this point. As, however, matters of such importance were concerned, the greatest possible advantage should be taken of these results. A crude approximation to the absolute tenacity could be obtained by taking the average of the two relative tenacities, which referred respectively to the initial and the broken sections. By an easy calculation the following results were obtained :—

No.	Quenching Temperature, Degrees C.		Contraction of Area Per Cent.	Broken Area Per Cent.	Tenacity 1000 lbs. per square inch		
					of Initial Area.	of Broken Area.	Absolute.
6, 7, 4, 16, 15	880 to 733	} Above Ar₃. ₂ . .	3·00	97·00	212·9	219·5	216·2
12 18	714 713	} Beginning of Ar₃.₂ {	... 1·54	... 98·46	221·3 211·3	... 214·6	... 213·0
9	698	Middle of Ar₃. ₂ .	3·53	96·47	206·7	214·2	210·5
5 14 21 10	652 650 633 626	} Between Ar₃.₂ and { Ar₁	3·17 5·68 5·87 5·94	96·83 94·32 94·13 96·04	145·0 142·0 128·2 125·8	149·7 150·6 136·2 133·7	147·4 146·3 132·2 129·7
22	620	Beginning of Ar₁	5·60	94·40	121·1	128·2	124·6
11 3	600 599	} End of Ar₁ . . {	44·40 46·50	55·60 53·50	91·6 89·0	164·7 166·4	128·2 127·7 } 128·0
8 19 13 17 20 23	575 532 512 340 263 20	} Below Ar₁ . .	38·60 51·34 54·40 53·54 55·64 52·29	61·40 48·66 45·60 46·46 44·36 47·71	93·4 82·8 82·1 79·4 76·5 74·0	152·1 170·1 180·0 170·8 172·5 155·0	122·8 126·4 131·1 125·1 124·5 114·5 } 126·1
24, 25	not treated at all		52·52	47·48	94·0	198·0	146·0

An inspection of this table showed that the great diminution of tenacity, according to the ordinary definition, which accompanied

Ar_1, was changed into a large increase if the tenacity was referred to the broken section, and it became practically *nil* for the absolute tenacity. Therefore, if it were admitted that the absolute tenacity was sufficiently closely represented by the method employed, the following conclusions might be drawn:—

1st. The absolute tenacity began to diminish towards the middle of $Ar_{3,\,2}$, and after a rapid fall it acquired a definite value at the end of this period.

2nd. This definite value (about 125,000 lbs. per square inch) was that of annealed ferrite, containing 1·19 per cent. of manganese, &c.

3rd. In the mixture of martensite and ferrite, the absolute tenacity being that of the weakest element—the ferrite—it was seen that the absolute tenacity of the ferrite varied for bars hardened between 698 and 626° (the points $Ar_{3,\,2}$) with the temperature of hardening. This might be ascribed to the conservation of a decreasing proportion of the iron of the ferrite in the β-state under the influence of a permanent pressure, whether positive or negative, caused by the change of volume which accompanied this transformation.

4th. The absolute tenacity was decidedly much greater in untreated bars than in those hardened after the end of $Ar_{3,\,2}$ (Influence of cold-working.)

5th. In the mixture of martensite and ferrite, the observed elongation could not give an exact idea of the elongation which the corresponding ferrite would naturally suffer if it were not mixed with an inextensible constituent.

6th. The great increase in elongation coincided with the end of Ar_1, because the inextensible element martensite was then replaced by perlite, which was deformable in itself, and could endure something like ten per cent. elongation.

Mr. JOHN PARRY considered that it was in many instances difficult to grasp Mr. Howe's meaning. He appeared on the whole to admit that the molecular changes observed by himself confirmed the results obtained by other well-known scientists, assisted, however, by the presence of what he termed chemically combined carbon, thus not absolutely attributing physical change to allotropy

alone. It was also suggested that there might be two forms of
allotropy—first, complete allotropic change—major allotropy;
second, incomplete change—minor allotropy; and stress was laid
on that distinction. If it were granted allotropic change occurred,
that distinction seemed of little practical utility. In saying that,
however, Mr. Howe clearly did not wish it to be inferred that
he was not an adherent of the allotropists, and quoted results
which in his opinion were confirmatory. He had on the whole
dealt very fairly with both sides of the question. Mr. Howe's
statement that the hardness of nickel steel and manganese steel,
as also other alloys, was in any way comparable with the glass
hardness of a quenched high-carbon steel could be confirmed.
For instance, Mr. Hadfield, describing the physical properties of
silicon steel, observed that silicon, unlike carbon, did not confer on
iron the property of becoming hardened when water-quenched.
It was, however, obvious that for some uses a material not very
susceptible to external influences, such as sudden heating, cool-
ing, or water-quenching, would undoubtedly prove useful. No
one, however, appeared to have succeeded in alloying iron, quite
free from carbon, severally with silicon, manganese, nickel, &c.,
and their knowledge of the absolute effect of those on iron only
remained incomplete. Hadfield himself considered that even as
low a percentage of carbon, equalling 0·09 or even less, might
have a considerable effect, and accordingly severely criticised
Professor Howe's deductions in favour of allotropy. Arnold abso-
lutely rejected Howe's figures. Iron should have been taken as
free as possible from impurities other than carbon; the curves
shown had no reference whatever to iron containing 0·21 per cent.
carbon, because he had dealt with an impure abnormal alloy of
iron, carbon, and manganese. One was fain to agree with both,
and without absolutely rejecting the allotropic theory, it seemed
clear that the peculiar disturbing effect which carbon undoubtedly
had on iron must be eliminated ere they could determine whether
allotropic forms of iron existed. He himself had for some time
past considered that the carbon-iron alloy formed a class apart
and quite distinct from the other iron alloys, and had repeatedly
drawn attention to that. Further, it appeared on reviewing the
discussion that the notable divergence of opinion for and against

allotropy was in a great measure due to the want of care in selecting adequately pure iron. It went without saying that iron containing at most traces of silicon, sulphur, phosphorus, &c., should be used. It was obviously impossible, however, to get the absolutely pure metal, *i.e.*, in quantity.

One could not be far wrong, " in the light of recent research," in assuming that carbon conferred unique properties on iron which required special study, prominently the unstable combinations which it apparently formed with iron, conferring physical properties on the material termed steel, obviously advantageous for certain uses, but certainly the reverse for others. It followed rationally, for the purpose of discussion, that the distinctive of carbon steel should be considered apart from what might be termed nickel, manganese, silicon, &c., steels. Possibly it would be better to classify the latter as metal-iron alloy, retaining the term steel for the carbon-iron alloy only. One might also study effect of elements other than carbon when alloyed with carbon steel.

Thus there were three distinct fields for research :—

1. Practically pure iron and carbon.
2. The same with silicon, nickel, manganese, &c.
3. Carbon iron alloy with silicon, &c.

Of course the latter was the common steel with tool Bessemer or extra soft steels.

As regarded the latter, they were in possession of a vast mass of crude facts which one might be excused for saying needed to be systematically classified. Their knowledge of classes 1 and 2 could not be said to be extensive.

Finally, as a practical worker in iron and steel, and as the outcome of a long and varied experience, he might say that he had noted irregularities in the quality which he could only attribute to allotropic change ; as a chemist he had repeatedly failed to give satisfactory reasons for the abnormal results shown in the manufacture. There was nothing new in that; it was the old story, very familiar, and alas of too frequent occurrence. It was more than probable that the true solution of those irregularities was to be found in the careful practical study of the remarkable molecular changes now proved to occur which might

be produced at will, simply by systematic manipulation, together with the rational application on the manufacturing scale of the modes of procedure shown to be necessary for the production of a given grade or quality of steel. He took it for granted that every variety of steel, whether a metal or a carbon steel, was more or less subject to notable molecular changes in strict accordance with heat, treatment, and subsequent manipulation. Recent research seemed to show that, and in many instances the necessary data were given, which not long ago were unknown, or at most only dimly guessed at. He might there remark that it was well known that wrought iron as puddle bar and its derivative contained a considerable proportion of carbon, often as much as rail steel, and in the case of puddle steel, sometimes ¾ per cent. Yet that material was not comparable with a cast steel; in spite of the carbon, it retained some of the characteristics of wrought iron. Had any satisfactory explanation been given, one was well aware that material like puddle bar was described as a mere bundle of detached grains of iron held together by the iron slag, the latter of which was squeezed out in the rolling, leaving elongated or fibrous iron longitudinally welded together, and not at all comparable with cast steel. That explanation, in his opinion, hardly accounted for the difference between the two. The assumption that in wrought iron or non-fused steel (so far as carbon was concerned), the iron was in the (a) or soft condition, would, if it could be proved to be true, afford a satisfactory explanation of the apparent softness of wrought iron containing a sensible proportion of carbon.

Many years ago he directed attention to that (Iron and Steel Institute, 1884), suggesting that iron might exist in two forms, (1) the colloid, and (2) the crystalline state (see Graham on the colloid and crystalline forms of matter), and that it was desirable to maintain steel for rails or specially soft material in form 1; at the same time, almost for the first time molten steel was compared with water, the one fluid say at 3000°, the other at the normal temperature of 60°, both were capable of holding foreign bodies in solution and obeying the usual laws governing the retention and precipitation of foreign matter present.

The opponents of allotropy most certainly had directed attention

to the important part which carbon played in determining the final quality of steel. That might be, but so far they did not appear to have succeeded in proving the entire absence of allotropic or molecular changes. There might be a "rearrangement or change of position of the particles or molecules;" shortly, the term allotropy did not need to be confined to the narrow limit laid down by Professor Arnold. The possibility of this had, however, been questioned; also that it was not allotropic change as defined by chemists. Practically, however, it amounted to the same thing; but it must be noted that these latter might not be stable, or, if so, within very narrow limits, under certain conditions. Further, it was held that a metal like aluminium, for instance, was composed of several elements of slightly varying atomic weight. There were many reasons for thinking that iron was of a similar complex nature. The results of actual research and experimental work might be quoted there, but that was needless, as they might be found in the published works of Professors Crookes, Lockyer, and many others.

Professor Arnold's definition on allotropy was ingenious, and, strictly speaking, true, but not quite conclusive. They could not ignore the broad fact that the elements were subject to molecular change, and in the case of an element like iron, so nearly allied by the periodic law to a group of other elements, such as manganese, &c., it was probable that its molecular state was an unstable one. One might, however, take it for granted that the peculiar action of carbon on iron required a further explanation; hence resulted a certain confusion and divergence of opinion. It would therefore be well, as previously said, to eliminate the disturbing element in future research, and so finally settle the point which Mr. Hadfield disputed, viz., that carbonless iron did not harden on quenching.

Professor W. C. Roberts-Austen, C.B., Member of Council, had recently expressed his views as to the hardening of steel in the discussion which followed the reading of two papers on the physical properties of iron and steel at the Institution of Civil Engineers in December last,* and he had now but little to offer except his thanks to Mr. Howe, and warm recognition of the

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* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii., 1896, p. 250.

value and usefulness of his communication. It was important to bear in mind that in the discussion before the Civil Engineers, Mr. Sauveur, who favours a carbo-allotropic theory, and is now associated with Mr. Howe in the authorship of the " Further Notes on the Hardening of Steel," had attacked what he called "the assumption" that the hardening of steel was due to the presence of a definite carbide, $Fe_{24}C$, and had most forcibly stated the case against such a view. The question of allotropy remains, therefore, the one on which attention must be concentrated.

In the present state of knowledge it is perhaps unnecessary to add anything to what had already been embodied by Osmond in the concise little communication to the present meeting, in which he clearly traced the parallelism between carbon-steels, nickel-steels, and manganese-steels, and showed that allotropy enabled their properties and behaviour to be explained, and by the arguments it contains brought metallurgists appreciably nearer the time when allotropy, in relation to iron and steel, would be as freely spoken of as the molecular mobility of gases or solids is now. An appeal had, however, been made to Professor Austen from many sides to define his views with regard to the meaning of allotropy, and especially as applied to the molecular changes in iron. In response to that appeal he would point out that allotropy might reveal itself either by a change in physical properties, including crystalline form, or by a change in the chemical activity of a substance, and in the case of sulphur and phosphorus both the crystalline form and the chemical activity changed. All were agreed that as, what was probably, the purest iron yet produced cooled down from bright redness to 850°, a change took place in the iron which is attended with evolution of heat.

This represents a critical change of internal energy of the iron. It corresponds to a true allotropic change, for the safest definition of allotropy that can be given is "a change of internal energy occurring in an element at a critical temperature unaccompanied by a change of state." Van't Hoff (whom Professor Austen had consulted), would, he gathered, prefer to substitute " not *necessarily* accompanied " for " unaccompanied." If the word "element" be replaced by " compound," it would become a definition of isomerism. It must be borne in mind that the distinction between an allotropic

or an isomeric change and a change of state is merely nominal. For instance, Professor Austen's definition would not entitle *solid* ice to be considered as an isomeric form of *fluid* water. An allotropic or an isomeric change did not always take place at a precise and definite temperature, but was spread over a range of temperature. The change of ice into water was the transformation of the lighter into the heavier "modification" of water, and as the maximum density of water was not at 0° but +4°, some solid molecules of the light modification must be retained in the fluid water for some degrees above the melting-point. Recent work on the diffusion of solid metals had confirmed the view to the existence of fluid molecules in solid metals, and there was also evidence that the passage of one modification of iron into another was not effected suddenly.

Change of energy is directly measurable by experiment; so that the above definition does not involve the mechanism of atoms and molecules, but if an appeal to them is considered necessary, then the evolution of heat, which occurs when iron and certain other elements cool down, may be due to two causes :—

1st. There might be a change in the *number* of atoms in the molecule (polymerism); or

2nd. A change in the *arrangement* of the atoms in the molecule.

As regards the question, was the allotropy of iron due to the first or second of these causes ?   Professor Austen considered that analogies with other allotropic inorganic bodies pointed to the probability that polymerisation, or a change in the number of atoms in the molecule, occurred as electro-iron was cooled down, a view which Ostwald accepts, for Professor Austen had taken advantage of a recent visit to the Mint of that great authority on molecular structure to submit the cooling curves of iron to him. Armstrong,[*] moreover, had already expressed the same view, and Professor Austen adduced the following reasons in support of it: The work of Ramsay and of Heycock and Neville pointed to the probability that in molten metals the molecules consist of single atoms, and, therefore, as the iron or other metals cool down, more and more atoms united to form a molecule, this polymerisation

[*] *Journal of the Chemical Society's Transactions*, vol. lxvii. 1895, p. 1164.

being attended with an evolution of heat exactly as was the case with sulphur and phosphorus.

It may be well to record the nature of the autographic curves which represented the evolution of heat in iron at 855°. They indicate that heat was released just as it would be if a change of state occurred (liquid to solid), and in general was quite different from the explosive evolution of heat in high carbon steel at 655°, at which point the carbon and iron changed their relations.

There need be no fear that the carbo-allotropic theory introduced any new principle into chemical theories. It did not involve the retention of the allotropic form of an element in its compounds. The presence of carbon, as had so often been pointed out, enabled a particular molecular condition to be retained, thereby maintaining the analogy of carbon-irons and solutions. It is known[*] that the number of atoms in a molecule of a dissolved substance might depend on the nature of the solvent, and that the molecular change in iron (855°) was lowered by the presence of carbon, just as the freezing-point of water was lowered by the presence of a salt.

Apart from the older work of Osmond and of Barus on the influence of stress, some recent experiments appeared to show that subjecting metals to stress conferred on them a directional change or polarity, comparable to the magnetisation of steel. It remained to be seen whether that polarisation was not accompanied by allotropic change in the stressed steel, and the work of Varenne and of Senderens[†] supported that view by showing that iron subjected to stress had, when compared with unstressed iron, a different chemical activity conferred upon it, which afforded another forcible piece of evidence in favour of allotropy.

Mr. H. D. HIBBARD considered the paper by Messrs. Howe and Sauveur as another step forward in the campaign against the mysterious in the metallurgy of steel, which, it was hoped, would be vigorously pursued until steel-making was some day put, if not in, at least near the category of exact sciences. He believed, however, that after all available means in the study of the crystallography and mineralogy of iron and steel had been

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* Nernst: "Theoretical Chemistry," 1895, p. 387.

† *Bulletin de la Société Chimique de Paris,* vol. xv.-xvi. 1896, p. 691.

exhausted, it was necessary to go farther and endeavour to get knowledge of the molecular arrangements and the effects of other chemical ingredients beyond those generally determined. In the paper the authors had apparently not even considered the possible effect of the other prominent ingredients beside carbon in connection with the at present unexplainable points they had noticed. These other elements affected the physical properties, and might or might not follow the carbon in its formation of the mineral ingredients. If any of them did so it might be at different temperatures. It would be well to know the rate of cooling the test-bars underwent, as time might and should be a most important condition of the change from martensite to ferrite mentioned. The number of degrees required was noted, but the only mention of time was in the statement that the bars were cooled slowly. It would also probably be very instructive if the series of observations made for the paper could be also made on bars of the same steel of say one-tenth, and also ten times and one hundred times the area of cross section. This was not stated in any way in disparagement of the work done, which was by no means slight in amount, but only to call attention to the probability that the rate of cooling, governed partly by the size of the test-bar, should have an important bearing on the formation of the steel minerals. Similar study of steels representing the possible variations in chemical composition brought to the mind an infinite vista of experiment. There was one thing to be said about the martensite, which was that, in view of what was stated in the paper, there must be varieties of that mineral. The same piece of steel could not contain 100 per cent., 70 per cent., and 30 per cent. of martensite, the rest of the steel being ferrite, or nearly pure iron, all of the same composition. It would seem more likely that when the martensite was 30 per cent. it contained over three times the percentage of carbon it had when it constituted 100 per cent. of the steel. At first reading he thought he saw a reason why the bar No. 9, containing about 30 per cent. ferrite, was about as strong as the bars quenched above Ar_2, namely : That there was sufficient hard martensite in the bar to form a continuous framework across it, preventing the reduction of area. Such a condition seemed to raise the tensile strength in the following cases : First,

when a piece of boiler plate was tested in a short pulling section the tensile strength was much greater than that obtained from a relatively long section. This could be explained by considering that the extra metal at the ends of the short section had such a side-stiffening effect as to resist contraction of area to some extent, which kept the area of cross-section somewhat large, and thereby enhanced the tensile strength. Second, a piece of steel boiler plate pulled across the direction of rolling was stronger than if pulled in the direction of rolling. This was explained by considering that a sort of columnar structure was set up by the rolling which extended across the test-bar when that was taken so as to run across the direction of rolling, and this structure resisted to some extent the tendency to reduction of area under tensile stress. This explanation would not, however, account for the much lower tensile strength of bars 5 to 10, which had small reductions of area for the loss in strength.*

VOTES OF THANKS.

The CHAIRMAN said there was one other paper on the agenda by M. de Benneville on "A Study of some Alloys with Iron Carbides." Undoubtedly, after the discussion that had just taken place, that paper could not fail to be one of considerable interest. It would, however, be discussed by correspondence. The paper would be taken as read, and members would have the opportunity of studying it and sending any communication they desired to make to the Secretary.

He begged leave now to move, "That the thanks of the Iron and Steel Institute be, and are hereby tendered to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their room, and for the facilities otherwise afforded for the present meeting."

Sir JOHN ALLEYNE, Bart., Vice-President, had much pleasure in

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* Mr. Howe's reply to the discussion is unavoidably held over until the next volume, as the Secretary has received a letter, dated July 8th, stating that Mr. Howe is seriously indisposed, and that it will probably be some weeks before he can attend to business. In these circumstances Mr. Howe regrets that Professor Arnold's remarks, which he considers to be misrepresentations and unjust, should be printed without his being able to reply to them at once.

seconding the motion. He thought their special thanks ought to be conveyed to the Institution of Civil Engineers, for receiving kindred societies and affording them so much assistance in connection with their meetings.

The vote of thanks was carried unanimously.

Professor ARNOLD, in moving that the best thanks of the meeting be given to Sir Lowthian Bell for his conduct in the chair, said that the resolution wanted no words of his to support it, because in Sir Lowthian Bell they had the advantage, not only of a genial chairman, but also of a man of high authority on the matters discussed, which was a point of very great value in the president of a scientific meeting.

Dr. RIDEAL said he was sure that no words of his were needed in seconding a proposal of that kind. Although they all regretted the absence of Sir David Dale, they certainly could have had no better substitute than Sir Lowthian Bell, and he had great pleasure in seconding the proposal that the best thanks of the meeting be accorded to him for his presidency.

The vote was carried by acclamation.

The CHAIRMAN, in reply, said that he had been cautioned by members of his own family from undertaking any work in connection with the Iron and Steel Institute. His reply was that if there was anything that he knew of calculated to restore him to entire health it would be by his being permitted to meet his old friends connected with the Iron and Steel Institute. He desired to take that opportunity of expressing his belief, which he had no doubt was shared by every gentleman who had listened to the discussions at the present meeting, that none of their meetings had ever been conducted in a more complete and philosophical spirit. He could not help feeling a certain amount of self-congratulation, and he hoped of justifiable pride that he had been in any way instrumental in the creation of the Iron and Steel Institute. He was much obliged for the kind manner in which his services in the chair had been received, and as long as life and health permitted him he hoped to take part in the business of the Institute.

A STUDY OF SOME ALLOYS WITH IRON CARBIDES: MAINLY MANGANESE AND TUNGSTEN.

By JAMES S. DE BENNEVILLE (PHILADELPHIA).

THE present paper gives the results of some experiments carried out to ascertain whether any inferences could be drawn as to the structure of iron alloys in general by the use of a purely analytical method. The alloys made, in the main, the subject of study possess a peculiar interest from the valuable properties with which, separately alloyed with iron carbides, they are supposed to endow the resultant product. The data obtained, it is believed, all go to prove that the view taken of iron alloys in previous papers [*] is a correct one, and that commercial iron alloys are to be regarded not only as solid solutions of the minor constituents in the excess of iron present, but as also containing one, several, or perhaps many definite compounds formed by reaction in the liquid or pasty mass, and separating therefrom as their freezing-point is reached. Under such conditions the study of iron alloys is to be compared to the study of a mass of water containing dissolved a number of salts. Moreover, in such a system the relation of these different dissolved compounds to the solvent may differ. On lowering the temperature, therefore, some of these compounds may separate as their freezing-point is reached, or on separation may hold in combination part of the solvent, as in salts with water of crystallisation. Again, constituents may be present, assuming the solid condition simultaneously with the great mass of the solvent, and presenting a condition analogous to that found in cryohydrates, at best physical mixtures. The alloys of iron carbides with elements of the sixth family, owing to their chemical inertia, present facilities for such an examination not offered by more readily decomposable compounds. Their very high melting-point precludes any active participation except as they enter into solution (combination),

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[*] *Journal of the American Chemical Society*, vol. xvi. p. 297, 735; vol. xvii. p. 791; *Journal of the Iron and Steel Institute*, 1895, No. I., p. 202.

through their affinity for the liquid mass (iron), which is the dominant reactive element through its liquidity.   In reference to solids of like structure the alloys will be compared with the vitreous silicate rocks.

The alloys were made as before described.   The proportions taken were not based on equal weights, but on quantities taken in the ratio of the atomic masses of the constituents.   They were manganese and tungsten as $1:1$; $5:1$; $10:1$; $1:5$. The elements were weighed in these proportions, were intimately mixed and ground together, and a lump of cast iron imbedded in the mixture.   The furnace was brought to a white heat and kept so for one hour.   The melts obtained were treated as indicated in Table VI.   Graphite crucibles were used and the mixture covered with crushed charcoal.

FERRO-MANGANESE.

Before entering in detail into the structure of the ternary alloys it is expedient to examine the constituents.   In the case of ferro-manganese it is not necessary to depend on chemical evidence alone to establish the presence of definite compounds in the mass of the alloy, for this is shown by the crystalline form, which frequently takes a needle-like structure (as in A.), as pronounced as with ferro-chromium.   This structure, present in the two alloys examined, is often so well developed as to assume a more regular form, and to separate apparently as prismatic hexagonal crystals (as in B).*   As the composition of the alloy approaches that of spiegeleisen a tabular structure is developed. For the separation of such definite compounds, however, ferromanganese presents difficulties almost as great as with the iron carbides.   Distinguished by absorptive power for chemically combined carbon, ferro-manganese is decomposed with evolution of hydrocarbon, slightly by cold, readily by boiling water.   On solution in hot mineral acids a black residue is left undissolved, which has been shown to be, in the main, a reaction compound. This residue does not contain manganese.   In cold hydrochloric acid, 1·17 specific gravity, a considerable quantity of metallic

* See Bauerman, *Journal of the Iron and Steel Institute*, 1885, No. I., p. 203, citing Jeremeyen and Mallard.

residue is left undissolved. After extraction by carbon-disulphide and ether this residue shows under the glass (50 diameters) groups of crystals more or less definite in form and granular masses with brilliant metallic lustre. Also in the residue obtained after treating the alloy with strong bromine water an unattacked metallic residue is present with the carbon. In this residue the prismatic crystals found in specimen B. and the acicular crystals in A. are present, intermixed with the granular material, both, however, being so altered as to their carbon as to render their separation and analysis by this means useless. The crystals are also found in the residue after boiling the alloy with ammonium citrate solution. In bulk these residues form but a small part of the total mass, although their inertia is considerable, remaining unaltered even after a week's digestion.

The thermo-chemical researches of Troost and Hautefeuille [*] are the basis for the belief that manganese forms with carbon and silicon definite chemical compounds of considerable stability. Briefly, they established the fact that iron forms with silicon and carbon endothermic compounds, whereas the manganese compounds are decidedly exothermic. Therefore they regard the manganese compounds as of the nature of salts, and the iron as dissolving silicon and carbon, but not forming salts. Ferro-manganese does contain definite compounds to a much greater extent than iron, but the figures observed for the heat disengagement are not large, and to a great extent there seems to be, chemically speaking, but little difference between manganese carbide and iron carbide. Leaving out of consideration the formula (Fe_3C) of the one iron carbide so far isolated, there is little doubt that carbide of iron does exist as a definite chemical compound. Toward re-agents carbide of manganese—excluding the crystallised compounds—shows no more inertia than carbide of iron, and in some respects, in its reaction with water, considerably less. The difference between the two metals appears to lie in the fact that manganese has a much greater solvent power than iron for carbon ; by solvent power being meant the capability of forming those indefinite solution compounds, truly chemical in nature, but readily passing from one form to

[*] *Annales de Chimie et Physique*, Série 4, vol. ix. p. 56. For their calorimetric measurements they used Boussingault's method, viz., cold moist mercuric chloride.

another, and uniting in varying proportions to form compounds strictly limited by the law of definite and multiple proportions. Such solution compounds have long since been classed by Mendeléef under this law.* In addition, manganese evidently forms compounds strictly limited in composition, as shown by the sharply defined crystalline form. In iron carbide this is found in the platy structure of the carbide Fe_3C. With manganese the form passes from the broad platy structure through several forms to the acicular and prismatic structure, due either to varying conditions of formation or to varying composition, or probably both. The acicular or prismatic structure is to be attributed to the manganese compound, as it appears more and more perfectly with rise in the manganese percentage, and is not found in the iron carbides.† In both ferro-manganese and spiegeleisen a ternary carbide is present. Also in manganese steel. Using an electrolytic method of decomposition, Arnold and Read ‡ obtained from normal and annealed bars of such steel (1·73 per cent. manganese) as residues, "powders having a light-grey metallic appearance." The annealed bar gave the formula Fe_7MnC_3, and the normal bar $Fe_{17}MnC_8$, which latter they regard as "a double-carbide of iron and manganese, with a little free-carbon present from decomposition of the double-carbide."

For the purposes of the present paper two samples of ferro-manganese were examined, marked A. and B. A. was used for making the alloys with tungsten. The experiments took two directions. In Table I. the residues obtained by treating A. and B. with hydrochloric acid of 1·17 specific gravity are given. A large excess of acid was taken. In Tables XII. and XIII. are given the residues obtained on treating B. with hydrochloric acid of 1·19 specific gravity, the volume of acid and weight of metal taken being constants, the water, *i.e.*, dilution, varying. In both cases the ferro-manganese was added to the acid in small portions at a time, the vessel being cooled externally by cold water to prevent rise in temperature from reaction. When all action had ceased, the residue was separated by filtration from the acid solu-

* *Principles of Chemistry*, vol. i. p. 65, note 19; vol. ii. pp. 112 and 113. Including alloys and the indefinite silicates. True solution is invariably accompanied by change in form of the dissolving substance.

† *Journal of the American Chemical Society*, 1895, vol. xvii. p. 791.

‡ *Journal of the Chemical Society, Transactions*, vol. lxv. p. 788.

tion.   It was then washed with alcohol, transferred to a flask, and extracted with carbon–disulphide and ether, separated from the liquid by filtration, well washed with 95 per cent. alcohol, and dried at 125°.   By this treatment coarse powders, ranging from grey to brown-black in colour, were obtained, showing under the lens the granular structure described.   These residues showed great differences.   The residues of Tables I. and Nos. 3 and 5 of Table XII. were free from such impurities as oxidation products, more particularly silica.   As to the metallic portion, the residues represent in part a structure originally present in the alloys, inasmuch as they consist mainly of iron and manganese combined with carbon and silicon; but there is also present notable quantities of hydrogen, and sometimes oxygen and nitrogen.   The exact nature of this hydrogen and nitrogen is doubtful; and whether they are to be regarded as forming nitride and hydride of iron, or as occluded or dissolved in the iron, is undetermined.   The composition of ferro-manganeses A. and B. is found in Table V.

TABLE I.—*Residues by Cold HCl.   Ferro-manganese.   Taken for analysis two grammes.*

Elements.						French A.	American B.
Iron .	.	.	.	.	.	0·0840	0·0916
Manganese	.	.	.	.	.	0·5100	0·6138
Silicon	.	.	.	.	.	0·0294	0·0110
Carbon	.	.	.	.	.	0·3756	0·2780
Phosphorus	.	.	.	.	.	0·0010	0·0056

Taken in connection with what the microscope shows of the structure of these residues, two facts are brought out by the proximate analysis, viz., the complexity of the granular part, and the heterogeneity of the residues taken as a whole.   This heterogeneity was determined as follows: Microscopically and analytically (as in the residues of Table I.), and by the variation shown in Table XII., a considerable portion of the silicon present in the alloys was concentrated in the residues as silicide.   All manganese was dissolved, but the iron and phosphorus which escaped solution by the acid were present to form the compound Fe_3P (but slowly attacked even by hot acids), and hence the phosphide is an iron phosphide, and

not a double phosphide with manganese. The third insoluble constituent was carbon. As hydrocarbons are evolved freely, the main constituent, from the composition given in the Table, is present as carbide, and from the large percentage of manganese present its carbide is the dominant constituent. A still further differentiation is obtained on treating the alloys with strong aqueous solution of bromine or iodine. There is a marked difference shown in the Table (II.) in the quantity of iron and manganese found, for these constituents are present in but trifling proportions to their total bulk as present in the alloy. In fact, there is as great a difference between the cold acid residues and halogen residues as there is between the cold acid residues and the soluble portion. Silicon and phosphorus are both present in diminished quantity. No carbon determinations could be made in such residues, as, apart from separated carbon, the residues were much altered by the reagent, as was shown by the characteristic blue and yellow coloration. The phosphorus is much in excess of the quantity required to form Fe_3P, and a lower phosphide may be present or the manganese may be present partly as phosphide. The appreciable loss of phosphorus and silicon shows these elements to be constituents of the cold acid residue. The bromine residue shows under the glass the granular structure, and when present in the samples taken the prisms are also found. It forms but a small part of the acid residue, and as to bulk is to be regarded as an unimportant impurity. It then remains to determine whether this granular residue, by cold acid or by bromine, is a mixture of carbide and silicide, or but one compound, a silicocarbide? As inclusions are present, to view it as a mixture of carbide and silicide is according to this analytical evidence. Moreover, the difference in colour shown by the granules, passing from the white of the metal to blue and straw yellow, offers cumulative evidence, although not convincing, for iron carbides show this difference when practically pure, and its presence is only an indication of heterogeneity requiring corroborative evidence. If the granules be taken as mixture of carbide and silicide, it is necessary to accept in the alloys the presence of two carbides, the carbide constituent of these granules being insoluble in cold dilute acid, whereas the other is readily soluble. Abundant

analytical data—the microstructure of iron alloys—show such association of two carbides to be of common occurrence. Acid and bromine, therefore, if regarded as solvents of certain constituents, from a heterogeneous substance made up of many compounds, would show these granules to be a heterogeneous mixture of at least four compounds—phosphide, carbide, and silicide of iron and graphite. But Prost* in his experiments on white iron showed that the composition of such residues varied with the strength of the acid. The temperature of solution he fixed at 85°. Four important facts were established by his work: 1. That beyond a certain concentration increase in the strength of the acid did not decrease the proportion of the residue. 2. On dilution of the acid the proportion of hydrogen, carbon, and phosphorus diminished. 3. But the proportion of iron increased. 4. Hydrogen was a constituent of the residue. The variation in composition, however, with the strength of the acid, renders it doubtful if these residues are definite compounds. Mixtures they unquestionably are as far as included phosphide and graphite

TABLE II.—*Reactions of Ferro-manganese with Hot Acids and Halogens in the Cold. In Sulphuric* (1 : 4), *Hydrochloric,* 1·17 *Specific Gravity, and Nitric,* 1·20 *Specific Gravity, Acids the Alloys left no Insoluble Iron or Manganese.*

Conditions: Excess of strong aqueous solution of the Halogen, digested in the cold for seven days.	Bromine.		Iodine.	
	Ferro-manganese.	Ferro-manganese.	Ferro-manganese.	Ferro-manganese.
Elements.	A.	B.	A.	B.
Iron	0·0048	0·0059	0·0049	0·0050
Percentage of total iron .	3·19	3·50	3·19	2·90
Manganese . . .	0·0044	0·0059	none	none
Percentage of total manganese . . . }	0·64	0·77	none	none
Silicon	0·0040	0·0019	0·0017	0·0017
Percentage of total silicon	74·1	40·4	31·5	36·2
Phosphorus . . .	0·0012	0·0012	0·0008	0·0008
Percentage of total phosphorus . . . }	48·0	48·0	32·0	34·8
Ratio of iron to manganese (Fe : Mn) . . }	1 : 1	1 : 1	n : 0	n : 0
Formulated . . .	$Fe_9Mn_8Si_{14}P_4$	$Fe_{10}Mn_{10}Si_7P_4$	$Fe_{12}Si_8P_4$	$Fe_{14}Si_9P_4$

* *Bulletin de l'Académie Royale de Belgique,* vol. xvi. pp. 216–232. "For determined concentration there is a solution of certain constituents, carbides, phosphides, &c., the others remaining unattacked " (p. 217).

are concerned, but mixture of silicide and carbide cannot explain varying action of acid on slightly altering the concentration.   As this variation exists not only between two different samples of iron, but between residues obtained from the same specimen by acids of different strength, difference in combination between the constituents due to different methods of working or cooling cannot be called in to explain it.   The assumption of a large number of carbides, phosphides, &c., removed at different concentrations is cumbrous ; and, moreover, such compounds, as far as can be judged from known examples, have a much wider range of stability than these acid residues.   This phenomenon of variation in solubility is not confined to iron alloys, but is found in the silicates as shown by Mackintosh.*   Strength of acid is an important factor in solution.   The analysis of residue B. in the Table (I.) shows better the composition of the cold acid residues taken in reference to the whole mass of the alloy.   The hexagonal prisms of B. were confined to the central portion of the alloy, and it was easy to obtain a sample representing ferro-manganese of distinctly granular structure.   Sample A. was made up of acicular masses arranged in bundles and distributed throughout the whole mass of the alloy, thus introducing a disturbing factor.

Leaving out of consideration, therefore, the sharply-defined crystallised compounds, what relation exists between the variable residue and the soluble portion of the ferro-manganese ?   The ready decomposition of the combined carbon by boiling water, and the evolution as hydrocarbons, shows a weak bond between such carbon and the mass of the alloys.   If there is reason to believe that in a certain class of iron carbides (hardening carbon) the iron dissolves the carbon, but does not form definite compounds with it, there is much more reason to believe it of a considerable proportion of the combined carbons of high-grade ferro-manganese.   The question of the nature of these solution compounds need not be discussed in this connection, but it can be asked whether the carbon in such case answers to the condition called by Van-t-Hoff† the "solid" solution, and whether

* *Journal of Analytical and Applied Chemistry*, vol. i. p. 10.   Also Sterry Hunt, "Systematic Mineralogy."

† *Zeitschrift der Physikalische Chemie*, vol. v. p. 322, or Nernst, "Theoretical Chemistry," p. 146, translated by Palmer.

Mendeléef's conception of the law of definite and multiple proportion can be applied to carbides of such nature in the same sense as to indefinite silicates.   In the reaction between iron and carbon, iron plays a double part, for it forms carbide, and this carbide is dissolved in the excess of metal present.   This is shown by the two states of combined carbon, viz., " cement " carbon in the form of definite carbide, Fe_3C, separating at lower temperature, and " hardening " carbon formed at high temperatures.   To this latter it is not yet possible to give any definite formula, or to isolate it from the mass of the alloy.   Now, the union of carbon and iron in the combined condition—whether hardening or cement—requires an elevated temperature.   In the blast-furnace iron combines with the maximum quantity found in iron carbide alloys.   If the melt is allowed to cool slowly, the greater part of the carbon so dissolved crystallises out in the form of graphite,[*] and but a small portion remains combined with the iron.   To retain the carbon in combination with the iron it is necessary to cool rapidly from an elevated temperature.   The chemical bond between the iron and carbon is not strong enough to prevent decomposition of the iron carbide on slow cooling. If, now, a solution of a salt in water be taken—for instance, sodium sulphate—a condition is found analogous to that present in the iron alloys.   This salt forms with the solvent (nH_2O) two definite compounds, $Na_2SO_410H_2O$ at $27°-34°$, and $Na_2SO_47H_2O$ below $26°$; and these salts are independent of each other, and their stability is conditioned only by the concentration of the solution and the, temperature.   Moreover, if their temperature of formation be passed, a third compound free from solvent, the anhydrous salt, Na_2SO_4, separates (at $40°$).   According, therefore, to the temperature conditions, from the solution of sodium sulphate the anhydrous salt or the two hydrated salts are obtained, and such separation, moreover, can be prevented under the proper conditions, and although saturated and below their freezing-point, separation of solid does not take place. Solidification then, when brought about, takes place suddenly throughout the mass, without differentiation and with marked development of heat.   In the saturated solution of carbon in iron—as found in pig iron—the irregularities found in the

* Especially in the presence of silicon.

thermal curves on heating or on cooling, taken in connection with the microscopic examination and proximate chemical analysis show much the same condition, for, as stated, the condition of the carbon is directly dependent on the temperature and conditions of cooling.   That this view of the relation of carbon to iron is correct is also shown by dilute solutions of carbon in iron, as illustrated by the series, passing from high carbon tool steel (1 + per cent. carbon) to mild steel (·25 − per cent. carbon), and to wrought iron containing but a trifling quantity.   In fact, the thermal phenomena exhibited at the two points, V and W,* generally agreed to be associated with change in condition of the carbon, take place at a temperature remarkably constant for different classes of steel, and are markedly accentuated and concentrated as the carbon increases.   With decrease, however, as in mild steel, the reaction takes more time to complete itself, is more spread over, the temperature limits for its occurrence a not unusual property of chemical reaction, in which active mass is the important factor in the equation representing chemical change, and on which the physical properties of solutions depend according as the concentration is great or not.   The structure of iron alloys can be well understood from the analogous structure of the glassy silicates.   There is no question that such silicates are chemical compounds, although no definite formulæ can be given to them.   According to the conditions of cooling, great variation is therefore found, and a series is obtained ranging from vitreous structure to a highly crystallised rock mass made up of definite compounds.   To such silicates of porphyritic nature, and more particularly to those whose vitreous ground mass is crowded with microlytic forms, iron alloys are to be compared, containing crystallised from the mass a number of definite compounds varying in the extent of their development, and with the major bulk of the mass combined in the indefinite form.   And it is to the vitreous ground mass that the granular material of

* Howe: "Heat Treatment of Steel" (*Transactions of the American Institute of Mining Engineers*, vol. xxiii. pp. 494-518), points out the analogy between the thermal phenomena and those accompanying surfusion of saline solutions ♯47. His experiments ♯25-♯47 show that hardness depends more on the total extinction of the V change than of any particular part of it, especially if above V itself. There is, then, apparently a sudden radical change within certain narrow limits of temperature, and not a gradual relieving of stress. V and W therefore represent points in an arithmetical series, not a geometrical. Chemical change not mechanical.

indefinite composition is to be compared. When the graphite, phosphide, sulphide, or definite carbide are abstracted, this ground mass remains varying from one alloy to another, whereas these definite compounds are probably common to all iron alloys; but this ground mass is as truly chemical as the vitreous ground mass; its constituent elements are combined, not free.

Ferro-manganese and iron carbides can then be described as heterogeneous masses, their constituents ranging from the sharply crystallised compounds, prismatic or octahedral in form, to in-definite compounds, analogous in nature to vitreous silicates. From the absence of manganese in the phosphide isolated, this element is probably present even in ferro-manganese as phosphide of iron (Fe_3P).[*] The prismatic carbide does not give an iron reaction by the blow-pipe and is non-magnetic. In silicon the indefinite granular residue as silicide is often an integral con-stituent of such residue, and this is also the case with carbon. The shining black plates found in graphitoidal pig iron are also present in ferro-manganese A. and B.[†] The presence of free elements held dissolved in the iron is unnecessary, and the reaction between such dissolved " free " carbon and nascent hydrogen is evidence in itself of the chemical nature of the union with iron or with each other. Their ready decomposition is only an illustration of the relation between volume and stability, and is found in the silicates, whether of natural or artificial formation.[‡] Between the residue insoluble in cold acid and dissolving on heating it is not necessary to differentiate. It is to be taken as a homogeneous whole, indefinite in composition. Some of the constituents are more readily soluble than others, according to the nature and strength of the reagent used, and hence remain as a residue under conditions unfavourable for their solution. It is the ground mass of the alloy, analogous in nature to the vitreous portion of some volcanic rocks.

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* Probably as phosphide of iron, for phosphorus and sulphur are not infrequently found in segregations; but it is possible that the phosphide obtained as above represents the insoluble residue (radical) of a more complex compound in the original alloy, and in the present state of the chemistry of iron alloys the simpler explanation cannot be positively asserted.

† Only found by examination of a large sample. The quantity present is trifling.

‡ Sterry Hunt: "Systematic Mineralogy," pp. 97–99 and 101.

IRON, MANGANESE, AND TUNGSTEN IN THE ALLOYS.

Before entering on the discussion of the results obtained from the proximate analysis of the alloys this premise is to be stated, viz., that when the constituents of a compound in their uncombined form are acted on by a reagent, and when with the compound itself, whether it be alloy or solution, under the proper conditions the reaction does not take place, it can be accepted that chemical combination has taken place inert (to that reagent) under the stated conditions.   And this implies inaction only under such conditions, for an alteration of temperature, pressure, or other physical concomitants, reaction may take place.   Such a premise is to be taken in its entirety, for while it is conceivable that phosphides or carbides of iron are formed insoluble or unattacked by a reagent, it cannot be accepted that phosphorus or carbon attacked by it is present as such, for phosphides and carbides may and do exist unstable in their nature, and perhaps present, dissolved in the mass of iron and—a not unusual property of such a combination—readily altering their chemical status on alteration of external conditions.   While, therefore, chemical inertia is strong proof of chemical union, reaction is no proof to the contrary.   Such reaction would be suggestive of simple mixture when a reagent acts on one of the constituents of a compound and not on the other or others.   When, therefore, the reaction takes place with the compound, it can be accepted that the affinity between the reagent and constituent has been diminished only in degree, if at all (a matter of experiment), and that the force acting between the two is the measure of the affinity between the active constituents and the inactive constituents of the compound.   This, taken in connection with reaction between the constituents and other reagents may, and often does, indicate nothing but mechanical mixture, or at best physical mixture.

The method of analysis was much the same as employed with the alloys described in the previous paper.   It is sufficiently described in Tables V., VI., VII., and VIII.   On heating, all the alloys are decomposed by nitric acid.   The action was energetic. With sulphuric and hydrochloric acids but trifling quantities of iron are found in the residue.   This is in marked contrast with

the results obtained with the ternary alloys of the sixth family, with iron carbide, or with the results obtained with ferro-tungsten. The ratios formulated do not represent compounds. The residual tungsten can be taken as that not yet attacked by the reagent, for hydrochloric acid acts but slowly on tungsten. The action of sulphuric acid is noteworthy. The acid does not attack metallic tungsten, but, with the exception of X., X-B., and XI., considerable quantities of this element are removed from the alloys. Of these three alloys, X. and X-B. give every indication that chemical combination has not taken place. They are as dark as the cast iron used as solvent. X-B. was annealed, changing from the brilliant white of X-A. to a dark lustrous steel-grey. XIII., however, which in appearance is like X., loses half its tungsten to sulphuric acid. Increase in solubility must be due to change in condition of the tungsten, and from the action of XIII., to be associated with ferro-tungsten. It has been shown that these ferro-manganeses are readily decomposed by hot acid. Throughout the entire series of the ternary alloys with tungsten manganese does not appear in the residue after treatment with acids. In ternary alloys of the sixth family, with iron carbides, the quantity of iron in such residues is, as a rule, a considerable percentage of the total iron present, and with ferro-tungsten rich in tungsten this is the case. Hence, not only has tungsten present shown no tendency to form inert compounds with manganese, but itself holds but little iron insoluble to acid reagents. The dominant influence in the alloys is that of manganese, as far as their chemical nature is concerned. It requires a considerable proportion of manganese and tungsten to bring about combination with manganese when tungsten is present. In the X. series and in XIII. manganese drops to an insignificant figure. The percentage of tungsten, however, in X., &c., is too small to bring out the peculiarities of rich ferro-tungstens, and in XIII. there has been absorption without changing the condition of the carbon, although, judging from the action of the sulphuric acid, subdivision is already much advanced. In their action toward acids, therefore, there is no evidence to indicate the presence of ternary alloys, and manganese appears to exert on the tungsten a preventive influence in respect to its concentration in inert compounds, i.e., the formation of definite compounds.

Evidence as to ternary alloys is to be sought in the reactions of the alloys with the halogens.   Pure iron or manganese, when digested with strong aqueous solution of bromine or iodine, are converted to the corresponding halogen salts.   Tungsten is attacked by bromine solution in the cold readily and completely, but iodine only attacks it on heating.   Ferro-manganese leaves a residue containing manganese and iron probably in the form of carbide and phosphide.   This residue, however, contains but a trifling part of the total quantity of manganese found in the alloy, and this is markedly the case even in ferro-manganese containing over 70 per cent. of manganese.   The total bulk of such residue is minute.   Ferro-tungsten, however, under such conditions, gives considerable residue.   In the alloys to be examined, therefore, the ratios formulated for the bromine residue can be taken as representing compounds in which the question is—are the manganese and tungsten present together chemically, or is there merely a mechanical mixture of two residues, one due to ferro-manganese and the other to ferro-tungsten ?   Although the percentage of manganese present in these alloys is much smaller than that present even in low-grade ferro-manganese, yet when found it always represents a considerable percentage of that present in the alloy, the lowest being that of XII-B., 10·76 per cent.   The iodine residues show a considerable increase, except in the case of the bar XI. A and B, quenched and unquenched respectively, which show a curious reversal and remarkable agreement in both cases.   Where the carbon is not present as combined carbon, manganese disappears altogether from such residues, showing that it is to be attributed to inert carbide, as is the case in ferro-manganese itself; and from the percentage of manganese found, when present at all, probably as ternary carbide, although, as shown by the action of acids, dominated by the characteristics of manganese rather than of tungsten carbides.

In Table III. the decrease of iron with increase of manganese over tungsten in the alloy appears.   This refers not to the figures as found in the table, for these represent merely the quantity of the compound or compounds as found in that particular alloy, but to the proportions existing between the constituent elements. With the exception of the ferro-tungsten, X-A., the bromine formulas are very much alike in the proportions of the elements

TABLE III.—*Iodine and Bromine Residues.*

Alloy.	X-A.	XI.	XI-A.	XI-B.	XII.	XII-A.	XII-B.
Iron-bromine residue . . .	0·1186	0·0448	0·2244	0·2387	0·0139	0·0360	0·0640
Iron-iodine residue . . .	0·2074	0·1381	0·1838	0·1773	0·1719	0·3073	0·4004
Manganese-bromine residue	0·0066	none	0·0414	0·0380	none	none	0·0145
Manganese-iodine residue	0·0108	0·0466	none	0·0081	0·0317	0·0573	0·0881
Tungsten-bromine residue .	0·0339	0·0177	0·0639	0·0680	0·0238	0·0184	0·0372
Tungsten-iodine residue . .	0·0615	0·0874	0·0454	0·0321	0·0686	0·0372	0·0686
Bromine residue formulated .	Fe_{71} Mn_4W_6	$Fe_{33}W_4$	Fe_{49} Mn_9W_4	Fe_{59} Mn_8W_4	Fe_2W	$Fe_{13}W_2$	Fe_{24} Mn_6W_4
Iodine residue formulated .	Fe_{89} Mn_4W_7	Fe_{26} Mn_7W_4	$Fe_{33}W_4$	Fe_{84} Mn_4W_4	Fe_{83} Mn_4W_4	Fe_{110} $Mn_{21}W_4$	Fe_{78} $Mn_{15}W_4$

present. Increase of manganese, however, as shown in passing from X-A. to XII-B., gives an evident diminution in the quantity of residue found, *i.e.*, as the soluble constituents increase. The lack, however, of close agreement would appear to show that these residues are either mixtures of carbides, &c., and perhaps containing alloyed iron and manganese, or else that the combination effected in such an alloy, although possessing chemical resistance, varies with the composition of the alloy from which it is obtained. That is, that iron and manganese do not form such a compound of definite structure with tungsten as is found in compounds with chromium carbides—for instance, Wahlite and Garrisonite. For if such were the case, although the bulk of the residues might vary, yet the proportions between the constituents would be much the same. But this is not the case for the series X., XI., or XII., which show no such agreement. That a compound of iron and manganese is present uncombined with a metalloid is unlikely. For in ferro-manganese the small residue left on bromine treatment gives the characteristic tints, and is to be regarded as a carbide mixed probably with other kindred salts of iron. And from the trifling bulk of this residue in the great mass of manganese and iron present, it is evident that iron and manganese have but little tendency to form compounds confined · to the metals. Where the prismatic crystals as found in ferro-manganese are present, variation can be explained on differing

proportions of granular and prismatic residues. But in these
ternary alloys the form is dominated by the granular structure
of ferro-tungsten. There is no appearance of prismatic structure,
and the residual masses are finely granular. Some light is
thrown on the subject by the composition of the iodine residues.
In these residues the excess of tungsten that appears is to be
disregarded, for this can be set down to tungsten unattacked
under the conditions. Tungsten unattacked in a bromine residue
can be taken as also present in the iodine residue. Where both
residues then are found in an alloy, there is a marked increase in
the content of iron. Is this to be ascribed to addition to the
residue of compounds insoluble in this reagent, or is part of the
iron held in such form as to be attacked and removed from the
compound by bromine? In the series, with one exception,
iron increases in the iodine residues. In XI., XII., and XII-A.
manganese absent in the bromine residue appears in the iodine
residue. Disregarding the tungsten, it will be found that while
related in their proportions the difference between the residues
is well marked. Placing the manganese compounds in order:—

$$Fe_{110}Mn_{21}, \quad Fe_{84}Mn_{4}, \quad Fe_{83}Mn_{6}, \quad Fe_{82}Mn_{4}, \quad Fe_{78}Mn_{18},$$
$$Fe_{71}Mn_{4}, \quad Fe_{53}Mn_{3}, \quad Fe_{46}Mn_{9}, \quad Fe_{36}Mn_{7}, \quad Fe_{24}Mn_{6}.$$

The entrance of iron and manganese into these residues would
therefore appear to be governed entirely by the conditions at-
tending the genesis of the alloy. Otherwise it would have to
be accepted that a large number of tungsten compounds are
formed, which, from the almost uniform proportion of tungsten
present (W_4), is hardly likely. As stated, increase in tungsten
accompanies increase in iron, and hence increase in complexity
of the resultant compound. This can only be based on the
bromine residues. Placed in a series:—

$$131-4 : 89-4 : 86-4 : 66-4 : 33-4$$
$$96-4 : 88-4 : 75-6 : 57-4 : 30-4$$

the variation is found to lie almost entirely in the iron man-
ganese constituent. The data are too few to draw any more
general conclusion. The proportion of manganese in these
bromine residues to be attributed to unattacked ferro-manganese
is so small that the greater part of this element is to be taken
as entering into a ferro-tungsten; the proportion between the

residues and the total mass of the alloy is much greater than is the case with ferro-manganese, but only in XI-A. and XI-B. does the proportion of such residue reach high figures, and in this bar there is marked increase in inert tungsten.

Finally, in what form is the material soluble in acid solvents to be regarded as present ?   Iron and manganese dissolve completely in cold acid.   Tungsten is but slowly attacked even by hot boiling hydrochloric acid.   In the alloys, however, and in ferro-tungsten this is not the case.   Hydrochloric acid dissolves such tungsten in considerable quantities, and sulphuric acid and cold aqueous solution of iodine remove as much.   Such tungsten is therefore to be regarded as combined tungsten, a constituent of a soluble compound containing iron and manganese, in virtue of which combination it dissolves.   In these ternary alloys, tungsten appears to enter as a constituent of the ground mass, and to share in its chemical activity toward reagents.   Moreover, if the alloy attacked be a commercial iron carbide, it will be found that it is not pure hydrogen that is evolved, but a complex gaseous mixture of volatile hydrogen compounds, which fact in itself indicates that solution is accompanied by decomposition of compounds existing in the alloy itself, and not to be attributed to the acid.   It is doubtful, therefore, whether in such an alloy, when treated with acid, it can be said that metallic iron is being dissolved, for, interrupt the solution on removal of the outer portion, on again treating the residue the same phenomena are obtained.

The manganese tungsten iron carbides can then be taken as presenting the same general structure as is found in ferro-manganese and iron carbides.   1. Definite inert chemical compounds are present, forming carbides, phosphides, silicides, &c. There is not the marked differentiation as found in ternary carbides of the sixth family, and tungsten exerts but little influence in the direction of inertia on manganese present in the alloy.   They act independently of each other.   2. The ground mass of the alloy, readily decomposed by reagents.   In bulk this greatly predominates over the insoluble portion.   As uniformity in composition is to be sought in metallurgical results, this should add to the usefulness of such alloys, and not detract from it.   Solution compounds are more to be desired than an

agglomeration of definite compounds.   Dealing purely with the chemistry of this subject, it is not the province of this paper to draw conclusions as to the metallurgical application of the data obtained, but attention can be called to the independence of action spoken of, manganese and tungsten exercising independent action on the solvent iron; * such a condition simplifies very much the simultaneous use of these two elements in an iron alloy, and apparently offers a promising field of investigation. Acicular structure was entirely absent from the alloys, although, on chilling, strong radial structure was brought about in X-A., and not effaced in X-B.

SILICON, CARBON, PHOSPHORUS, AND NITROGEN.'

The details are found in Tables V., VII., and VIII.

Silicon.—Turner † has shown the absence of graphitoidal silicon in iron carbon alloys.   The earlier experiments of Morton ‡ on Bessemer pig iron had shown this element to be present in commercial iron as silicide of iron, which from its inertia, when heated in hydrogen to bright red heat, he regarded as only reduced by this gas with great difficulty.   In Tables V. and VIII. is given the action of hydrochloric acid on the manganese-tungsten alloys.   In accordance with Morton's and with Turner's results all the silicon found in this hydrochloric acid residue is present as silica.   Reaction between the acid and silicon in iron has been shown by Dr. Drown § to depend on the strength of acid used.   With strong acid the silica separates to a large extent as silica.   With dilute acid a considerable quantity remains in solution.   The same results are obtained with such silicates as are decomposed by acid or on acidifying an alkaline solution of silicate.   In iron alloys between silica dissolved by the acid and silica converted to gelatinous silica no distinction is to be made; but it will be found that if the residues obtained

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* For the ternary compound (Bromine residue) is readily attacked by acids, and shows no such sharp differentiation between ground mass and granular residues as is found with the ternary carbides mentioned.

† Jordan and Turner : *Journal of the Chemical Society's Transactions*, vol. xlix. p. 215. Turner: *Journal of the Iron and Steel Institute*, 1888, No. I. p. 28.

‡ *Journal of the Iron and Steel Institute*, 1874, No. I. p. 102.

§ *Transactions of the American Institute of Mining Engineers*, 1878, vol. vii. p. 346.

with dilute acid be examined under a lens (50 diameters) there is often no evidence whatever of the presence of silica. Between such unattacked silicon and the oxidized silica a distinction is to be drawn, possibly of such nature as to represent silicon of inert silicide and silicon a constituent of the ground mass. The small quantity of silica after treatment with bromine, and the presence of silicon in the granular residue, shows this element to be in the main a constituent of the indefinite ground mass.

Carbon.—This element is present in these ternary alloys in at least three forms:—(1) The nitric acid residue, which is free from iron or metallic base other than tungsten; (2) carbon evolved by acid as ill-smelling hydrocarbons; (3) carbon of the granular residue. In ferro-manganese there are at least three forms:—(1) Carbon evolved by acid as hydrocarbon; (2) manganese carbide of prismatic structure; (3) combined carbon of the granular residue. This carbon, however, can hardly be separated from the carbon evolved as hydrocarbon by cold acid. To chemical reagents—and apart from their microstructure—pure iron carbides give like results, although inert carbide is less positive in its nature. However, by appropriate methods a carbide, to which the formula Fe_3C (hydrated) is assigned, can be separated; volatile hydrocarbon is likewise evolved. Of this volatile carbon (hardening carbon ?) Osmond says * that its true state " is less accurately known, but it appears probable that it is that of free carbon simply dissolved in the iron, or perhaps that of hydrocarbon." Ledebur † differentiates still further by adding a "graphitic temper carbon," insoluble in strong acid, but eliminated on heating the metal for some time under oxidising influences; also, it is described as unlike graphite in appearance, being completely amorphous, deep black, and without lustre. Research on the condition of carbon in iron alloys, following Fourquignon's ‡ early researches on the different graphites obtained from such alloys, has been very extensive. The question arises as to distinguishing secondary forms due to reaction from the primary forms present as carbide in the original alloy. This is discussed more fully in the following section, in which the

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* *Journal of the Iron and Steel Institute,* 1890, No. I. p. 44, citing also Fourquignon.
† *Stahl und Eisen,* vol. viii. pp. 742-747.
‡ *Annales de Chimie et de Physique,* Série v. vol. xxiii. pp. 510-515.

solution of iron alloys in acids, and the resulting complex reaction, is viewed as a process giving rise to "products," as distinguished from "educts."

Phosphorus.—This can be taken as present mainly as phosphide of iron.   Freese * formed three phosphides, Fe_3P_4, Fe_2P, and FeP. Almost insoluble in cold hydrochloric acid, they were slowly decomposed by hot acid with formation of phosphoric acid and phosphine.   That the phosphorus is not present in the alloys as Fe_3P_4 is shown by the failure of hydrogen to remove any of the phosphorus on heating at a red heat in this gas.   The residue selected for this examination was the residue after treatment with strong bromine water in the cold, in which Fe_3P_4 is insoluble.   Phosphorus is present, therefore, as FeP, Fe_2P, or Fe_3P. Schneider † isolated from a number of cast irons a compound of the latter formula, and it is also present in ferro-manganeses A. and B.   As the reaction with acid given by Freese holds for the alloys (Table V.), the action of bromine and iodine may be taken as the reaction of this compound.   In addition to a volatile phosphorus compound, oxychloride is probably formed, and the gaseous and dissolved condition of the phosphorus are not to be differentiated.   Where the alloy is not attacked under strong oxidising conditions, all the soluble phosphorus is not in the higher form of oxidation, and before determination must be fully oxidised to phosphoric acid.   There is a difference in condition found in the small but appreciable quantity unattacked even by long-continued boiling with hydrochloric acid.   Soluble phosphorus (in bromine and cold acid) can be taken as belonging to the ground-mass.   The results obtained by the use of ammonium citrate solution of 1·09 specific gravity are striking, and recall Cheever's ‡ results.   It was objected that reaction between the oxide present and the decomposing phosphide would furnish the phosphoric acid obtained by his method.   Dennis and Cushman,§ however, in a recent paper showed the insolubility of FeP in ammonium citrate solution, and using this solvent found soluble

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* *Poggendorf's Annalen,* vol. cxxxii. p. 225.

† Howe : "Metallurgy of Steel," 55 ; from *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* 1886, p. 735.

‡ *Transactions of the American Institution of Mining Engineers,* 1886, vol. xiv. pp. 448, 938 ; J. B. Mackintosh. *Ibid.,* p. 452.

§ *Journal of the American Chemical Society,* 1894, vol. xvi. p. 477.

phosphorus in Bessemer steel.   The figures given in Table V.
show very marked quantities of soluble phosphorus, not only in
the alloys but in the samples of commercial iron there given.
Where the presence of phosphorus was established in the citrate
solution by direct determination, the organic acid was destroyed
by evaporation with strong sulphuric acid, and phosphorus then
separated by the usual methods.   It is necessary, therefore, either
to accept the presence of phosphide not only dissolved by the
reagent but converted to oxide, or to regard the soluble phos-
phorus as present as phosphate.   As, however, a considerable
percentage of the phosphorus is readily oxidised and dissolved
by other reagents, under conditions in no way necessitating the
presence of phosphate to bring about solution, solubility and
insolubility in the ammonium citrate solution merely establishes
the presence in the alloys of an insoluble phosphide.   Soluble
phosphorus may be present as phosphate or as a constituent of
the readily attacked ground-mass of the alloy.   This is a question
for future determination.

Nitrogen is discussed under Gases in Iron.

MANGANESE *versus* TUNGSTEN.

That manganese and tungsten form a ternary compound is
shown by the bromine residues in the white alloys X-A.–XII-B.
containing in such residues a marked proportion of the total
manganese present much in excess of what under like conditions
is found with ferro-manganese.   This compound differs but little
from the soluble material.   It readily dissolves in hydrochloric
acid.   As the insolubility of the manganese is to be directly
traced to the tungsten present in this residue, it shows the
influence the two elements exert in the alloys.   Ferro-tungsten
presents marked inertia to chemical reagents, but in these alloys
this bromine residue or the original alloy dissolves in acid,
leaving no manganese, and but a small quantity of iron as
residue with unattacked tungsten ; but the ferro-tungsten is still
able to resist the action of bromine.   It presents properties
marking a step between the soluble ground-mass and definite
insoluble compounds found in the ferro-tungstens.   In deter-
mining the relative affinity of manganese and tungsten for iron,

the formation of such a compound has no influence, as is shown in the accompanying Table IV.   The absorption of tungsten is

TABLE IV.—*Manganese versus Tungsten.*

Alloy.	Element.	Analysis. 1.	Analysis. 2.	Average per Cent.	Ratio Found.	Ratio Taken.
X.. . . .	Manganese . .	0·0288	0·0285	0·0287	1·00	1·0
X.. . . .	Tungsten . .	0·1643	0·1666	0·1655	1·71	1·0
XI. . . .	Manganese . .	0·1246	0·1243	0·1244	4·52	5·0
XI. . . .	Tungsten . .	0·0920	0·0931	0·0925	1·00	1·0
XII. . . .	Manganese . .	0·1547	0·1553	0·1550	6·56	10·0
XII. . . .	Tungsten . .	0·0793	0·0799	0·0796	1·00	1·0
XIII. . . .	Manganese . .	0·0085	0·0085	0·0085	1·00	1·0
XIII. . . .	Tungsten . .	0·2567	0·2564	0·2566	9·20	5·0

Alloy.	Element.	Analysis of A.	Analysis of B.	Average per Cent.	Ratio Found.	Ratio Taken.
X. A and B. . .	Manganese . .	0·0128	0·0131	0·0130	1·00	1·0
X. A and B. . .	Tungsten . .	0·1018	0·1032	0·1025	2·30	1·0
XI. A and B. . .	Manganese . .	0·1089	0·1096	0·1093	3·68	5·0
XI. A and B. . .	Tungsten . .	0·1000	0·0992	0·0996	1·00	1·0
XII. A and B . .	Manganese . .	0·1359	0·1353	0·1356	6·00	10·0
XII. A and B . .	Tungsten . .	0·0773	0·0779	0·0776	1·00	1·0

obviously independent of manganese, and iron combines with it much more readily.   When an excess of tungsten (5 : 1) is taken, manganese in the resultant alloy sinks to the trifling percentage present in the cast iron taken for smelting.   It can be recalled here that tungsten was shown to form compounds which from reactions and physical properties showed greater chemical inertia than either chromium or molybdenum, but that these elements combined more readily with iron.   The combination of iron with tungsten in preference to manganese can be accepted as showing greater affinity for metals of the sixth family than for the metal of the seventh.

GASES PRESENT IN IRON.

In addition to the constituents present, presumably in the solid form, in iron, certain gaseous elements have been identified, and the question as to the form in which they are present has always aroused considerable discussion.   Are they present as gases held mechanically entangled in the pores of the metals ? are they held in chemical combination, as is believed to be the

TABLE V.—Composition of the Alloys.

Proximate Analysis.	X.	X.-A.	X.-B.	XI.	XI.-A.	XI.-B.	XII.
Total carbon	0·0370	0·0513	0·0523	0·0586	0·0526	0·0535	0·0698
Carbide decomposed by nitric acid of 1·20 specific gravity	0·0226	0·0398	0·0355	0·0458	0·0453	0·0419	0·0543
Carbon in nitric acid residue *	0·0133	0·0115	0·0168	0·0128	0·0063	0·0116	0·0155
Total silicon	0·0167	0·0161	0·0165	0·0135	0·0128	0·0125	0·0050
Silicon in hydrochloric acid solution	0·0015	0·0019	0·0012	0·0045	0·0039	0·0045	0·0055
Silicon in hydrochloric acid residue	0·0152	0·0142	0·0153	0·0094	0·0089	0·0093	0·0095
Silicon attacked by sodium carbonate fusion	0·0019	....	....	0·0021	0·0009	....	0·0035
Silicon in HCl residue after treatment with HFe.	none	none	none	none	none	none	none
Total phosphorus	0·0029	0·0026	0·0025	0·0030	0·0018	0·0017	0·0025
Phosphorus evolved by hydrochloric acid	0·0019	0·0014	0·0012	0·0016	0·0012	0·0008	0·0006
Phosphorus in hydrochloric solution	0·0006	0·0006	0·0010	0·0011	0·0003	0·0005	0·0014
Phosphorus in hydrochloric residue	0·0004	0·0006	0·0003	0·0003	0·0003	0·0004	0·0005
Phosphorus attacked by sodium carbonate fusion	0·00037	....	....	0·00041	0·00110	....	0·00077
Phosphorus in ammonium citrate solution	....	0·0010	....	0·0019	0·0008	0·0004	....
Phosphorus in ammonium citrate residue	0·0021	0·0006	0·0004	0·0006	0·0008	0·0015	0·0021
Phosphorus in bromine solution	0·0012	0·0019	....	0·0008	0·0005	0·0004	0·0006
Phosphorus in bromine residue	....	....	....	0·0020	0·0011	0·0016	0·0020
Phosphorus in bromine residue—heated in hydrogen—red heat	0·0028	....	0·0024	0·0018	0·0009	....	0·0020
Phosphorus in iodine solution	....	0·0005	....	0·0009	0·0004	0·0005	0·0008
Phosphorus in iodine residue	....	0·0018	....	0·0023	0·0012	0·0016	0·0018
Phosphine evolved (AgSO₄ solution)	none	....	....	none	none	....	none
Manganese	0·0287	0·0128	0·0131	0·1244	0·1089	0·1096	0·1550
Tungsten	0·1635	0·1018	0·1032	0·0925	0·1000	0·0992	0·0796
Iron	0·7492 (D)	0·8158 (D)	0·8124 (D)	0·7080 (D)	0·7239 (D)	0·7285 (D)	0·6781 (D)
Sulphur	....	....	....				
Specific gravity	....	7·967	7·784	7·901	8·257	8·054	8·032
Formula	....	$Fe_{27}Mn_4W_{10}$	$Fe_{27}Mn_3W_{10}$	$Fe_{11}Mn_{12}W_4$	$Fe_{25}Mn_7W_2$	$Fe_{25}Mn_7W_2$	$Fe_{17}Mn_{26}W_4$
Volume change: contraction + ; expansion −	....	0·215+	0·042+	0·048−	0·476−	0·273−	0·280+

* With X. and XIII., to some extent this is graphite ; carbon associated with tungsten is present, and on long continued heating with strong nitric acid, with removal from time to time of the protecting coating of yellow tungstic hydrate, the alloy is completely decomposed. The results given were obtained with nitric acid of 1·20 specific gravity, and part of such carbide is almost certainly removed. Examination for phosphine was made by dissolving 5 to 10 grammes in dilute sulphuric acid, passing the gas through strong $AgSO_4$ solution, and testing with molybdate the nitric acid solution of the precipitate. D=by difference.

TABLE V.—(continued).

Proximate Analysis.	XII.-A.	XII.-B.	XIII.	Grey Cast Iron, B.	Charcoal Pig Iron, 1.	Ferro-Manganese, A.	Ferro-Manganese, B.	Tungsten for Steel.
Total carbon	0·0674	0·0668	...	0·0331	...	...	0·0618	0·0343
Carbide decomposed by nitric acid of 1·20 specific gravity	0·0530	0·0629	0·0135	0·0039	...	...	...	...
Carbon in nitric acid residue*	0·0144	0·0039	0·0074	0·0286	...	...	...	0·0039
Total silicon	0·0204	0·0216	0·0011	0·0224	0·0101	0·0064	0·0047	...
Silicon in hydrochloric acid solution	0·0018	0·0012	0·0063	...	...	0·0007	trace	...
Silicon in hydrochloric acid residue	0·0186	0·0204	0·0023	...	...	0·0047	0·0053	...
Silicon attacked by sodium carbonate fusion	0·0024	0·0024	...	...	...	0·0026	...	...
Silicon in HCl residue after treatment with HFe	none	none	...	...	...	...	...	...
Total phosphorus	0·0019	0·0016	0·0015	0·0024	0·0012	0·0028	0·0023	trace
Phosphorus evolved by hydrochloric acid	0·0016	0·0006	0·0008	...	...	0·0014	0·0011	...
Phosphorus in hydrochloric solution	trace	0·0007	0·0007	...	...	0·0011	0·0007	...
Phosphorus in hydrochloric residue	0·0003	0·0003	trace	...	...	0·0003	0·0005	...
Phosphorus attacked by sodium carbonate fusion	0·00023	0·00013	0·00043	...	...	0·0008	...	...
Phosphorus in ammonium citrate solution	0·0003	0·0005	0·0007	0·0012	0·0007	0·0012	0·0009	...
Phosphorus in ammonium citrate residue	0·0016	0·0013	0·0015	0·0024	0·0010	0·0013	0·0012	...
Phosphorus in bromine solution	0·0009	0·0007	0·0003	0·0002	0·0003	0·0012	0·0013	...
Phosphorus in bromine residue	0·0012	0·0009	0·0005	...	...	...	0·0012	...
Phosphorus in bromine residue—heated in hydrogen—red heat	0·0011	0·0009	...	...	...	0·0013	0·0013	...
Phosphorus in iodine solution	0·0007	0·0005	...	...	...	...	...	...
Phosphorus in iodine residue	0·0014	0·0014	none	...	...	...	0·0008	...
Phosphine evolved (AgSO₄ solution)	...	...	0·0085	0·0071	0·0006	0·0008	0·0008	...
Manganese	0·1359	0·1353	0·2566	...	...	0·7866	0·7644	none
Tungsten	0·0773	0·0779	...	...	...	...	...	0·9593
Iron	0·6971 (D)	0·6968 (D)	...	0·9347 (D)	...	0·1505	0·1684	0·0007
Sulphur	...	...	...	0·0003	0·0005	...	...	...
Specific gravity	8·368	8·063	8·096	7·474	...	7·288	...	15·175
Formula	$Fe_{97}Mn_{13}W_2$	$Fe_{96}Mn_{13}W_2$	$Fe_{24}Mn_4W_{87}$	...	...	...	...	...
Volume change: contraction+; expansion−	0·630+	0·225+	0·091+	...	...	...	...	...

TABLE VI.—*Manganese Tungsten Irons. Relation between Iron, Manganese, and Tungsten, after Treatment with Reagents. Proximate Analysis.*

Description.	Alloy.	Elements.	H_2SO_4, 1·17 Specific Gravity and Concent.	HCl, 1·18 Specific Gravity.	Bromine Strong Aqueous Solution.	Iodine Strong Aqueous Solution.
Button cooled with furnace. Fine grained crystalline grey iron. Not scratch glass. Furnace only bright red.	X.	Iron	0·0031	0·0036	0·0147	0·0073
	,,	Per cent. of total iron	...	...	...	...
	,,	Manganese	none	none	none	none
	,,	Per cent. of total manganese	none	none	none	none
	,,	Tungsten	all	0·0953	0·0266	0·1213
	,,	Per cent. of total tungsten	all	57·72	16·07	73·29
	,,	Ratio Fe : Mn : W.	1:0:17·8	1:0:8	1·9:0:1	1:0:5
	,,	Formulated	Fe_4W_{71}	FeW_8	Fe_2W	FeW_5
White Iron. Cast in rod. Mould chilled. Hackly fracture. Structure radial from centre. Deeply piped. At right angles to crystallisation resisted fracture. Brittle and hard. Scratched quartz. Before quenching fracture porcelanic.	X-A.	Iron	0·0008	trace	0·1289	0·2177
	,,	Per cent. of total iron	0·10	trace	15·80	26·69
	,,	Manganese	none	none	0·0066	0·0108
	,,	Per cent. of total manganese	none	none	52·4	85·7
	,,	Tungsten	0·0337	0·0335	0·0339	0·0615
	,,	Per cent. of total tungsten	33·10	33·10	33·30	60·21
	,,	Ratio Fe : Mn : W.	1:0:18	0:0:n	1·9:1:1·5	20·4:1:1·74
	,,	Formulated	FeW_{18}	Wn	$Fe_{33}Mn_2W_3$	$Fe_{33}Mn_4W_7$
Rod X-A. Annealed at red heat. Scratched quartz readily. Colour, steel blue. Radial structure.	X-B.	Iron	0·0008	0·0012	0·0172	0·0636
	,,	Per cent. of total iron	0·10	0·15	2·12	7·83
	,.	Manganese	none	none	none	none
	,,	Per cent. of total manganese	none	none	none	none
	,,	Tungsten	0·0706	0·0666	0·0156	0·0451
	,,	Per cent. of total tungsten	90·63	85·49	15·12	43·70
	,,	Ratio Fe : Mn : W.	1:0:38	1:0:18	2·66:0:1	4·71:0:1
	,,	Formulated	FeW_{38}	FeW_{18}	$Fe_{11}W_4$	$Fe_{19}W_4$
Button. Cooled with furnace. White iron. Brittle. Scratched quartz.	XI.	Iron	0·0023	0·0012	0·0448	0·1381
	,,	Per cent. of total iron	0·32	0·16	6·32	19·50
	,,	Manganese	none	none	none	0·0466
	,,	Per cent. of total manganese	none	none	none	37·46
	,,	Tungsten	all	0·0798	0·0177	0·0874
	,,	Per cent. of total tungsten	all	86·27	19·13	94·49
	,,	Ratio Fe : Mn : W.	1:0:12·5	1:0:21·5	8·33:0:1	5·23:1·78:1
	,,	Formulated	Fe_2W_{25}	Fe_2W_{43}	$Fe_{33}W$	$Fe_{26}Mn_7W_4$
White iron. Rod quenched from red heat in water at 30°. Piped. Steel blue along pipe. Hackly fracture. Brittle. Scratched quartz.	XI-A.	Iron	0·0189	trace	0·2350	0·1838
	,,	Per cent. of total iron	2·61	trace	32·46	25·39
	,,	Manganese	none	none	0·0414	none
	,,	Per cent. of total manganese	none	none	38·01	none
	,,	Tungsten	0·0422	0·0426	0·0639	0·0454
	,,	Per cent. of total tungsten	42·20	42·60	63·90	45·40
	,,	Ratio Fe : Mn : W.	1·78:0:1	0:0:n	12·1:12·2:1	13·2:0:1
	,,	Formulated	Fe_7W_4	Wn	$Fe_{40}Mn_7W_4$	$Fe_{53}W_4$

TABLE VI.—(continued).

Description.	Alloy.	Elements.	H$_2$SO$_4$, 1·17 Specific Gravity and Concent.	HCl, 1·18 Specific Gravity.	Bromine Strong Aqueous Solution.	Iodine Strong Aqueous Solution.
Rod XI-A. Not quenched. Fine Mould chilled. Fine grained. Porcelanic fracture. Pipe lined with flat white crystals. Brittle. Scratched quartz.	XI-B.	Iron . .	0·0018	0·0010	0·2474	0·1773
	,,	{ Per cent. of total iron . . }	0·25	0·13	33·96	24·34
	,,	Manganese .	none	none	0·0380	0·0081
	,,	{ Per cent. of total manganese . }	none	none	34·67	7·40
	,,	Tungsten . .	0·0261	0·0324	0·0680	0·0321
	,,	{ Per cent. of total tungsten . . }	26·31	32·66	69·55	32·36
	,,	Ratio Fe:Mn:W.	1:0:4·66	1:0:17·5	14·6:2:1	12:1·87:1
	,,	Formulated . .	Fe$_4$W$_{18}$	Fe$_2$W$_{35}$	Fe$_{56}$Mn$_8$W$_4$	Fe$_{34}$Mn$_4$W$_4$
Button. Cooled with furnace. White Iron. Fine grained. Scratched quartz.	XII.	Iron . .	0·0016	trace	0·0139	0·1719
	,,	{ Per cent. of total iron . . }	0·23	trace	2·05	25·35
	,,	Manganese .	none	none	none	0·0317
	,,	{ Per cent. of total manganese . }	none	none	none	20·45
	,,	Tungsten . .	0·0554	0·0548	0·0238	0·0686
	,,	{ Per cent. of total tungsten . . }	70·85	70·10	29·52	86·18
	,,	Ratio Fe:Mn:W.	1:0:10	0:0:n	2:0:1	8·3:1·54:1
	,,	Formulated . .	FeW$_{10}$	Wn	Fe$_2$W	Fe$_{33}$Mn$_6$W$_4$
Rod quenched from red heat in water at 90°. Coarsely crystalline on outer layers. Pipe obliterated, but scale crystals in its place. Brittle. Scratched quartz.	XII-A.	Iron . .	0·0019	trace	0·0360	0·3073
	,,	{ Per cent. of total iron . . }	0·27	trace	5·16	44·08
	,,	Manganese .	none	none	none	0·0573
	,,	{ Per cent. of total manganese . }	none	none	none	42·17
	,,	Tungsten . .	0·0271	0·0321	0·0184	0·0372
	,,	{ Per cent. of total tungsten . }	35·0	41·42	23·6	48·12
	,,	Ratio Fe:Mn:W.	1:0:4·7	0:0:n	6·4:0:1	27·4:5·2:1
	,,	Formulated . .	Fe$_4$W$_{19}$	Wn	Fe$_{13}$W$_2$	Fe$_{110}$Mn$_{21}$W$_4$
Rod XII-A. Not quenched. Fine grained. Pipe lined with blue scale-like crystals. Brittle. Scratched quartz.	XII-B.	Iron . .	0·0011	trace	0·0689	0·4004
	,,	{ Per cent. of total iron . . }	0·16	trace	9·88	57·46
	,,	Manganese .	none	none	0·0145	0·0881
	,,	{ Per cent. of total manganese . }	none	none	10·76	65·10
	,,	Tungsten . .	0·0517	0·0543	0·0372	0·0686
	,,	{ Per cent. of total tungsten . }	66·37	69·70	47·75	88·17
	,,	Ratio Fe:Mn:W.	1:0:13·9	0:0:n	6·15:1·3:1	19·3:4·3:1
	,,	Formulated . .	FeW$_{14}$	Wn	Fe$_{24}$Mn$_6$W$_4$	Fe$_{78}$Mn$_{18}$W$_4$
Button. Cooled with furnace. Graphitic coarse crystalline. Grey iron. Remelted. Not scratch glass.	XIII.	Iron . .	trace	trace	trace	0·0926
	,,	{ Per cent. of total iron . . }	trace	trace	trace	...
	,,	Manganese .	none	none	none	none
	,,	{ Per cent. of total manganese . }	none	none	none	none
	,,	Tungsten . .	0·1280	0·1694	0·0323	0·1304
	,,	{ Per cent. of total tungsten . }	50·0	66·01	12·59	50·82
	,,	Ratio Fe:Mn:W.	0:0:n	0:0:n	0:0:n	2·37:0:1
	,,	Formulated . .	Wn	Wn	Wn	Fe$_9$W$_4$

TABLE VII.—Phosphorus Percentages, from total Phosphorus.

Proximate Analysis.	X.	X.-A.	X.-B.	XI.	XI.-A.	XI.-B.	XII.	XII.-A.	XII.-B.	XIII.	Grey Cast Iron.	Charcoal Pig Iron, 1.	Ferro-Manganese, A.	Ferro-Manganese, B.
Phosphorus evolved by hydrochloric acid	65·5	53·9	48·0	53·3	66·6	49·0	45·7	84·2	37·5	53·3	…	…	50·0	47·8
Phosphorus in hydrochloric acid solution	20·7	23·1	40·0	36·6	16·6	29·4	40·0	trace	43·7	46·7	…	…	39·3	30·4
Phosphorus in hydrochloric acid residue	13·8	23·1	12·0	10·1	16·8	21·6	15·3	15·8	18·8	trace	…	…	10·7	21·8
Sum of phosphorus as gas and in HCl solution	86·2	76·9	88·0	89·9	83·2	78·4	85·7	84·2	81·2	100·0	…	…	89·3	78·2
Phosphorus attacked by sodium carbonate fusion	12·7	…	…	14·0	61·1	…	22·0	1·2	0·8	2·9	…	…	28·6	…
Phosphorus in ammonium citrate solution (by difference)	…	61·5	76·0	76·0	50·0	21·0	16·0	15·8	…	53·4	50·0	41·7	57·1	42·9
Phosphorus in ammonium citrate residue	…	38·5	…	24·0	50·0	79·0	84·0	84·2	43·8	46·6	50·0	58·3	42·9	57·1
Phosphorus in bromine solution	63·6	24·0	16·0	33·4	31·3	20·0	23·1	42·8	56·2	83·3	92·3	76·9	52·0	52·0
Phosphorus in bromine residue	36·4	76·0	84·0	66·6	68·7	80·0	76·9	57·2	56·2	16·7	7·7	73·1	48·0	48·0
Phosphorus in bromine residue—heated in hydrogen (Fe_3P)	…	…	85·7	60·0	56·3	…	76·9	52·4	…	27·8	…	…	52·0	52·0
Phosphorus in iodine solution	84·8	21·7	28·0	28·1	25·0	23·7	30·8	33·3	26·3	…	…	…	…	…
Phosphorus in iodine residue	…	78·3	72·0	71·9	75·0	76·3	69·2	66·7	73·7	…	…	…	28·6	34·8

TABLE VIII.—Carbon and Silicon percentages, from total Carbon and Silicon.

Proximate Analysis.	X.	X.-A.	X.-B.	XI.	XI.-A.	XI.-B.	XII.	XII.-A.	XII.-B.	XIII.	Grey Cast Iron, B.	Ferro-Manganese, A.	Ferro-Manganese, B.
Carbon decomposed by nitric acid 1·20 sp. gr.	61·1	77·6	67·9	78·1	86·1	78·5	77·8	78·6	94·1	…	13·6	…	…
Carbon in nitric acid residue	38·9	22·4	32·1	21·9	13·9	21·5	22·2	21·4	5·9	…	86·4	…	…
Silicon in hydrochloric acid solution	8·9	11·8	7·3	30·4	30·5	36·0	36·6	8·8	4·0	14·8	…	13·0	trace
Silicon in hydrochloric acid residue	91·1	88·2	92·7	69·6	69·5	64·0	63·4	91·2	96·0	85·2	…	87·0	100·0
Sum of silicon as gas and in HCl solution	18·5	20·5	47·3	44·5	47·0	41·6	45·2	20·5	17·9	18·8	…	13·0	…
Silicon attacked by sodium carbonate fusion	11·4	…	…	15·5	7·0	…	23·0	11·7	11·1	31·1	…	48·1	…
"Graphitoidal" silicon.	none	none	none	none	none	none	none	none	none	…	…	…	…

TABLE IX.—*Composition of the Gas evolved on treating Iron Carbide Alloys in the Cold with dilute Sulphuric Acid. Measurements reduced to 0° and 760 mm. Mercury Pressure.*

	X.	X.A.	X-B.	XI.	XI-A.	XII.	XII-A.	XII-B.	XIII	Ferro-Manganese, A.	Ferro-Manganese, B.
Composition as Evolved : Volume—											
Light hydrocarbons (C_nH_{2n-6})	none	none	none	none	none	0·20	none	none	none	none	none
Heavy hydrocarbons (C_nH_{2n})	0·41	0·20	0·20	0·28	0·41	0·41	0·42	0·18	0·17	0·59	0·51
Saturated hydrocarbons (C_nH_{2n+2})	none	none	none	none	none	none	none	none	none	none	none
Hydrogen sulphide	0·10	0·20	0·20	0·39	0·41	0·20	0·51	0·36	0·17	0·45	0·51
Carbonic oxide	0·94	4·35	1·64	1·16	1·14	2·40	1·07	2·79	1·65	1·65	1·08
Carbon dioxide and cyanogen	none	none	none	none	none	none	none	none	none	none	none
Oxygen	1·56	1·66	0·61	0·64	1·04	0·82	0·42	1·40	1·16	0·58	3·34
Hydrogen	85·41	81·17	82·22	83·40	78·02	86·41	83·89	75·41	79·16	82·93	70·32
Nitrogen	11·88	9·42	15·13	13·70	18·98	9·56	13·69	19·86	17·69	13·80	24·24
Eliminating Hydrogen: Residual Gas by Volume—											
Heavy hydrocarbons	2·75	1·26	1·12	1·73	1·86	4·49*	2·61	0·73	0·81	3·45	1·71
Hydrogen sulphide	0·67	1·26	1·12	2·41	1·86	1·49	3·16	1·46	0·81	2·62	1·71
Carbonic oxide	6·31	27·48	9·22	7·17	5·19	17·66	6·64	11·35	7·91	9·66	3·42
Oxygen	10·48	10·49	3·43	3·95	4·73	5·96	2·61	5·67	3·56	3·44	11·25
Nitrogen	79·79	59·51	85·11	84·77	86·36	70·40	84·78	81·79	86·91	81·83	81·91

* With light hydrocarbons.

TABLE IX.—*Composition of the Gas evolved in treating Iron Carbide Alloys*—(continued).

	Grey Cast Iron B.	Charcoal Pig Iron, 1.	Charcoal Pig Iron, 2.	Steel Axle.	Stay Bolt Iron.	Fire Iron.	Sheet Iron.	Meteoric Iron,* E. Tenn.	Commercial Aluminium ‡	Commercial Aluminium ‡	Pure Zinc.
Composition as Evolved: Volume—											
Light hydrocarbons (C_nH_{2n-6})	none	none	0·31	none	none	none	none	none	none	none	none
Heavy hydrocarbons (C_nH_{2n})	0·42	2·39	0·41	0·20	none	0·10	0·21	0·18	none	none	none
Saturated hydrocarbons (C_nH_{2n+2})	none	none	none	none	none	none	none	none	none	none	none
Hydrogen sulphide	0·42	none	0·53	0·61	none	0·60	0·62	0·52	none	none	none
Carbonic oxide	0·62	2·03	0·94	0·92	none	1·73	none	1·14	none	none	none
Carbon dioxide and cyanogen	none	none	none	none	none	none	none	none	none	none	none
Oxygen	1·73	0·90	1·05	1·05	1·05	2·39	2·21	3·01	none	none	2·70
Hydrogen	80·21	75·02	78·06	80·29	79·96	75·94	73·48	74·01	100·0	100·0	97·30
Nitrogen	16·19	19·56	19·70	16·93	18·99	19·24	23·48	21·14	none	none	none
Eliminating Hydrogen: Residual Gas by Volume—											
Heavy hydrocarbons	2·17	9·60	3·15†	1·01	none	0·41	0·79	0·69	…	…	…
Hydrogen sulphide	2·17	none	2·31	3·05	none	2·46	2·37	2·05	…	…	…
Carbonic oxide	3·19	8·16	4·09	5·43	none	7·19	none	4·38	…	…	…
Oxygen	8·92	3·62	4·58	6·20	5·24	9·93	8·33	11·59	…	…	…
Nitrogen	83·55	78·62	85·87	84·31	94·76	80·01	88·51	81·29	…	…	…

* For this specimen I am indebted to the late Dr. F. A Genth.   His description of this meteorite is found, *Proc. Acad. Nat. Sciences*, Philadelphia, 1886, p. 366.

† With light hydrocarbons.

‡ Hydrochloric acid used as solvent.

TABLE X.—*Carbonic Oxide and Nitrogen in the Gases evolved on treating Iron Alloys with Dilute Sulphuric Acid.*

Alloy.	Description of Metal.	Remarks.	Volume Ratio CO:N.	Molecular Ratio CO:N.	Composition. CO.	Composition. N.
X.	Manganiferous ferro-tungsten	Grey iron—Button cooled down with furnace	1:12·6	1:25·	0·94	11·88
X-A.	,, ,,	White iron—Cast rod—Heated to redness—Chilled in water 20°	1: 2·1	1: 4·5	4·35	9·42
X-B.	,, ,,	Grey iron—X-A. chilled—Annealed at red heat	1: 9·3	1:18·3	1·64	15·13
XI.	Tungstiferous ferro-manganese	White iron—Button cooled down furnace	1:11·8	1:23·9	1·16	13·70
XI-A.	,, ,,	,, —Cast rod—Heated to redness—Chilled in water 20°	1:16·7	1:32·9	1·14	18·98
XII.	,, ,,	White iron—Button cooled down with furnace	1: 3·9	1: 7·6	2·40	9·56
XII-A.	,, ,,	,, —Cast rod—Heated to redness—Chilled in water 20°	1:12·8	1:25·0	1·07	13·69
XII-B.	,, ,,	White iron—Cast rod—Mould chilled XII-A.	1: 7·8	1:14·2	2·79	19·86
XIII.	Manganiferous ferro-tungsten	Grey iron—Button cooled down with furnace	1:10·7	1:21·4	1·65	17·69
A.	French ferro-manganese	Acicular structure	1: 8·36	1:16·7	1·65	13·80
B.	American ferro-manganese	Granular structure	1:22·5	1:44·4	1·08	24·24
B.	Cast iron, grey	…	1:26·0	1:52·0	0·62	16·19
1.	Charcoal pig-iron	…	1: 9·6	1:19·0	2·03	19·56
2.	…	…	1:19·9	1:19·0	0·94	19·70
	Steel axle	…	1:18·4	1:41·2	0·92	16·93
	Stay-bolt iron	…	…	1:36·7	none	18·99
	Tire iron	…	1:11·1	1:22·5	1·73	19·24
	Sheet iron	…	…	…	none	23·48
	Meteoric iron	East Tennessee, near Cleveland—Described by Genth	1:12·9	1:25·6	1·14	21·14
	Commercial aluminium	Pittsburg	…	…	none	none
	,, ,,	Friahmuth	…	…	none	none
	Pure zinc	0·02 per cent. iron—Free from carbon	…	…	none	none

case in the absorption of hydrogen by palladium to form Pd_2H?
or are they in a state of occlusion or of solution, that compara-
tively unstable form of matter in which change of form—
reaction whether resulting in combination or allotropism—on
change of conditions is more readily effected? In this section
only such details are discussed as a method of analysis some-
what different from those heretofore adopted warrants, and this
involves the determination as to whether the elements present
in the alloys examined are in combination or mechanical mix-
ture. If definite compounds could be isolated, this would be of
great advantage, but the establishment of the presence of an
element in chemical combination, and not as such, has also its
value, and for this reason it was thought worth while to examine
the composition of the gases evolved on treating iron alloys and
iron carbides with acid.

Method.—Dilute sulphuric acid, 1·17 specific gravity, was
chosen as the solvent on account of its non-volatility, and the
reaction was effected in the cold. No attempt was made to
ascertain the ratio of the volume of gas evolved to the weight
of metal taken, and as the gas is largely the result of reactions,
the value of such relation is questionable. The apparatus
used for collecting the samples was very simple in construction.
It consisted of an ordinary carbon funnel, the narrow end
stoppered by a drawn-out glass rod, and connected with the acid
solution by rubber tubing closed with a pinchcock. The mouth
of the funnel was closed by a cork carrying capillary tubing,
and bent over to meet the gas burette. The sulphuric acid
and the water in the burette had been previously saturated by
passing through them gas evolved from the alloys. To carry
out the analysis, the pinchcock controlling the rubber tubing
connecting the acid reservoir and funnel was opened, and the
acid admitted to within an inch of the stopper. The alloy was
then dropped in the funnel and the gas allowed to pass off for
several minutes. When it ignited freely, funnel and burette
were connected, and 100 c.c. of the gas was taken and analysed
by Hempel's apparatus. The routine was as follows:—The gas
was shaken (1) with absolute alcohol and then with water,
measured—for light hydrocarbons; (2) potassium hydrate of
1·27 specific gravity—for carbon dioxide and cyanogen; (3) Nord-

hausen acid and the potash solution—for heavy hydrocarbons; (4) strong solution of silver nitrate—for phosphine and sulphuretted hydrogen; (5) alkaline pyrogallate—for oxygen; (6) ammoniacal cuprous chloride—for carbonic oxide; (7) an aliquot portion of the gas (15 c.c.) was taken, mixed with a measured volume of air, and exploded.   The contraction was measured; and (8) the residual gas was passed into the caustic potash pipette, drawn back, and the contraction, if any, measured.   7 and 8 gave hydrogen and the marsh-gas series.   The residue was taken as nitrogen (after experimental proof).   In several cases

TABLE XI.—*Qualitative Examination for Organic Compounds—Ferromanganese A—Treated with dilute Sulphuric Acid—Taken* 200 *grammes.*

Distillate . . .	Aqueous solution and a non-miscible yellow oil.	Black residue containing oil	
A. Ether Extract	Light yellow oil. Solidifying to a whitish yellow mass with paraffin odour. No volatile acid. No light rosin oil.	A. Alcohol solution	No resinous bodies. Yellow oil, solidifying with little or no odour. No organic phosphorus. Organic sulphur present.
B. Water Solution	No hydrocyanic acid, phenol, or sulphurous acid.	B. Alcohol treated residue	Combustion with soda-lime gave nitrogen (cyanides).
C. Saponifying .	Like results.	Acid solution . .	Hydrocarbon extracted by ether. No pyridine bodies, or cyanides.

Volatile phosphorus is not found in the AgNO₃ pipette (phosphine), or ammoniacal cuprous chloride pipette (with CO).

the hydrogen was absorbed by palladium, but the explosion method was subsequently adopted as more expeditious.

The gas obtained on dissolving iron or steel in hydrochloric or sulphuric acid can consist of gas occluded in the iron and set free on solution, or of gases formed by reaction between the solvent, the dissolving substance, or of intermediate products.   The conditions for the formation of hydrogen compounds are very favourable from the necessary presence of large quantities of nascent hydrogen.   On examining the results given in Table IX. it will be seen that three of the constituent gases are elemental, viz.

hydrogen, oxygen, and nitrogen, but the original status of the others is left undetermined by the analysis. The following paragraphs are devoted toward ascertaining, as far as the results admit, the origin of the gases and the reason for their genesis. Preliminary, therefore, to the study of possible reactions under such conditions, it is necessary to study the composition of the gases as they have been found to exist in iron or steel, and as obtained by mechanical methods of experiment. The data are very complete, and the composition has been well established for gas obtained from iron by cold boring, from the hot metal, from blowholes, and from the soaking-pit. The gases obtained on boring cold steel or iron under water consist mainly of hydrogen and nitrogen and a small quantity of carbonic oxide. The opinion generally expressed is that hydrogen escaping from cold bored iron is but feebly held by the iron. Parry,* accepting Matthiessen's dictum that "alloys are solidified solutions of one metal in another, made a number of experiments on the absorption of vapours by iron. He found that zinc, cobalt, cadmium, bismuth, and arsenic were absorbed by iron, and on reheating were again given up. Hydrogen acted in the same way, but phosphorus and sulphur were retained by the iron. Here was a marked difference, and the phosphorus and sulphur he regarded as forming chemical compounds with iron, but the volatile elements, including hydrogen, as forming alloys, i.e., as being dissolved in the iron. Howe † considers that the ready release by boring and heating, and the agreement with the results obtained by combustion methods, as also the expulsion by heat and rest of absorbed nascent hydrogen, point to a feeble combination between iron and hydrogen. Wanklyn and Carius,‡ however, by acting on zinc ethyl with ferrous iodide, obtained a metallic powder containing nearly $3\frac{1}{2}$ per cent. of hydrogen, to which compound they gave the formula FeH_2.

The nitrogen obtained by cold boring probably consists largely of mechanically held gas, or that in solution or occlusion, i.e., feebly combined in comparison with nitrogen as nitride of iron. On solution in acid it would be expected that if nitrogen be

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* *Journal of the Iron and Steel Institute,* 1874, No. I. p. 92; 1881, No. I. p. 183; 1884, No. II. p. 536. *Industries and Iron,* 1883.

† "Metallurgy of Steel," p. 110.   ‡ *Liebig's Annalen,* vol. cxx. p 69.

present in chemical combination as nitride, that in the presence of nascent hydrogen combination would take place, and that ammonia or nitrogen oxides, by secondary reaction, would be formed dissolving in the liquid, and hence diminishing the ratio of N : CO as compared to that found on boring the cold metal. In the large number of analyses of gases from cold-bored iron cited by Mr. Howe (Table 54, " Metallurgy of Steel "), it must be admitted that if the gases obtained by acid solution be compared with them, no such diminution is shown to hold as a rule.   And as analysis shows, the quantity of such combined nitrogen is small, the agreement in the relation found between these gases, from cold-bored and from acid-treated iron, shows that their origin is the same, and throws considerable light on the nature in which the cold-bored gases exist in iron.   Only this agreement need be noted here.   The comparison between Bessemer pig iron and Bessemer steel is interesting in this connection.   As the combination with nitrogen is much more favourable in the converter through which large volumes of air are forced, it would be expected that the proportion of N : CO would rise in the bored gas obtained from the steel; and so it does, as is seen in Nos. 36–39, as compared with Nos. 1–30 (Howe, cited).   Before leaving the question of the condition of the gases in cold-bored iron, the small quantity of carbonic oxide found is to be noted. In many samples it is not reported at all, and when reported the volume is small.   The highest percentages are found in pig iron, where the co-existence of oxide of iron and slag renders its genesis through reaction quite possible.   In blisters, carbon dioxide is found with it, and sometimes oxygen.

The gases evolved from hot iron have important reference to the present matter.   Numerous and complete data are given by Howe (Table 56, " Metallurgy of Steel ").   In these gases the volume of carbonic oxide has increased greatly.   The ratio N : CO is always diminished, and as a rule reversed, as compared with the cold-bored gases.   So also with hydrogen.   Indeed, there is often little or no diminution in nitrogen, but great loss of hydrogen. The presence or absence of carbonic oxide involves to some extent the carburation of iron, and the condition of the carbon when combined with iron.   A common ground of agreement among the different observers is the influence temperature has on the

evolution of carbonic oxide from iron.   Graham and Parry agree
that at low temperatures the main bulk of the gas given off by
different classes of iron is hydrogen, whereas at high temperature
carbonic oxide predominates.   Heating iron in carbonic oxide,
Parry [*] obtained in only one case absorption of the gas, and
when present in iron or steel he regards it as due to reaction
with oxide of iron or other oxides.   Troost and Hautefeuille,[†]
however, found that on heating cast iron or wrought iron in
carbonic oxide, that when subsequently heated in vacuo the pro-
portion of carbonic oxide had increased enormously in the gas
evolved, whereas with cast steel but little change took place.
Howe [‡] sums up the evidence as " creating a strong probability
that carbonic oxide does dissolve, but not strong enough to
prove it."   Reaction by cold boring or by acid solution takes
place at a comparatively low temperature.   Hence carbonic
oxide would be formed in such cases to a much more limited
extent than when reaction is brought about by heat, for the
formation of carbonic oxide requires a somewhat elevated tem-
perature.[§]   As now iron does not combine directly with carbon,
to form carbide, but requires the presence of chemically combined
carbon (carbonic oxide or cyanogen).   If, according to one theory
of the carburising (or cementation) process, the oxygen of carbonic
oxide acts as a carrier, a point must be reached marking the
saturation point of the iron for carbon at which the oxidised
carbon compound would be in the presence of a mass of hot
saturated (as to carbon) iron.   On solidifying, therefore, the iron
would retain this excess of carbonic oxide as such or as oxy-
carbide.   If the carbonic oxide in the cold-bored gases and
acid solution gases is due to setting free dissolved gas, it is to
be expected that in the volume of this gas set free the results
by the acid solution and by cold boring would agree to some
extent ; whereas with oxycarbide a greater volume of gas would
be found by acid solution.   Tables IX. and X. do show agree-
ment, but it is to be noted that carbonic oxide is invariably pre-
sent in acid solution gases, and is frequently absent from cold-

* *Journal of the Iron and Steel Institute*, 1874, No. I. p. 92.
† *Comptes Rendus de l'Académie des Sciences*, vol. lxxvi. p. 482.
‡ "Metallurgy of Steel," p. 124.
§ Lowthian Bell : *Journal of the Iron and Steel Institute*, 1871, No. I. pp. 135, 182.
Also Howe (cited 118 and 120).

bored gases, which is almost a bar to such explanation. And the analyses in both cases cover a considerable range. By the carbonic oxide theory of carburation the gas is decomposed to effect the combination of iron with carbon, the reaction taking place at 250°–500°. The carbonyl of iron discovered by Mond * volatilises at a comparatively low temperature, and retention in the mass of the hot metal should inevitably result in its decomposition. The presence of oxycarbide, therefore, would present difficulties as great as the carbonic oxide whose presence they are brought in to explain. At all events, the oxycarbide radical, a *rara avis* in the cold-bored gases, is of general occurrence in the acid solution gases, and the true state of the case would seem to be that the carbonic oxide in both cases is the result of reaction taking place at low temperatures, and its genesis would be more likely to occur on acid solution, as the Tables show. The only point in favour of the existence of the gas CO in cold-bored iron is found in the results of Troost and Hautefeuille, who obtained a considerable absorption by heating cast iron and wrought iron for forty-eight hours in the gas, and of Graham and of Parry, who obtained similar results with wrought iron. In reference to those experiments, however, Howe adds that there is no proof that the carbonic oxide was absorbed as such, and not by its constituents. Parry, throughout his papers, expresses his disbelief in the existence of carbonic oxide as such in iron and steel. There is this to be added, that there is no reason why grey cast iron and wrought iron should not absorb carbonic oxide on such heating. The cast iron contains its carbon mainly as graphite, and when placed under conditions favourable for the combination of carbon to form carbide, as ·in the case of these experiments, it would probably do so whether by the oxidation of its own graphite or by simple absorption limited by the length of the reaction and its capacity for combined carbon. The absorption by wrought iron can be similarly explained. Steel containing combined carbon absorbed but a trace of carbonic oxide.

That carbonic oxide is present in gases obtained from cold-

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* *Journal of the Society of Chemical Industry*, vol. xi. p. 750 (1892), from *Engineer*, June 10, 1892, p. 498. Physical constants of $Fe(CO)_5$ were : sp. gr. 1·466, boiling-point 102·8°, melting-point −21°, molecular weight 196, vapour density 6·5. $Fe_2(CO)_7$ also exists.

bored iron and hot iron is shown by the work of numerous observers. If the occlusion-solution theory and the oxycarbide theory are unsatisfactory, an explanation is reasonably to be sought in the reaction theory. The results now to be discussed are found in Tables IX., X., XII., and XIII. Of the constituents shown in the tables, hydrogen is evolved by the reaction between the iron and the sulphuric acid used as solvent. Oxygen may come from solution and reaction. Nitrogen, hydrocarbons, and carbonic oxide can only come from the iron itself directly or by reaction. Oxygen from secondary reaction could not be prevented.

According to Cloez,* it had been remarked by Proust (1799) that the combustible gas produced on treating iron and steel with hydrochloric acid was accompanied by a kind of essential oil, which condensed in drops on the sides of the vessel used for the solution, and that this oily product was also found in the black carbonaceous residue obtained by such treatment, and could be extracted by alcohol and subsequently precipitated by addition of water. Cloez therefore made an elaborate investigation into the hydrocarbon compounds found under such conditions. Treating 600 grammes of a crystalline spiegel-eisen (containing 4 per cent. carbon and 6 per cent. manganese) with dilute hydrochloric acid, he passed the gas in succession through water, pumice soaked in copper sulphate, and finally into a flask containing bromine covered by water. The hydrocarbons so obtained he then examined. The oily liquid by condensation he found to be lighter than water, very fluid, and boiling at 120° and upwards, according to the fractionation to which it was subjected. Of the numerous complex homologues he identified octylene. The bromine compounds he found to consist of a number of complex substitution products of the C_nH_{2n} series. From them he succeeded in separating the bromide of propylene. † There remained products not volatile at the decomposition temperature of the hydrocarbon bromides, and by heating with alcoholic potash he sought to obtain their hydrocarbons in a stabler form and simpler in composition. By such treatment he obtained the bromides of heptylene and octylene

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* *Comptes Rendus de l'Académie des Sciences*, vol. lxxviii. p. 1565.
† Ethylene he was unable to detect.

with an unidentified solid crystallised compound. He adds that grey pig iron gave him no oily hydrocarbon, and but little of the bromine compounds, these latter forming but $0·0001$ of the quantity of the pig iron taken, whereas with the spiegel he had obtained $0·01$ of the quantity taken in the form of oily liquid alone. From his very complete research it can therefore be accepted that the decomposition of carbide of iron by acid gives rise to hydrocarbons mainly, and probably entirely, belonging to the unsaturated series of formula C_nH_{2n}, and that of this series only the higher members, beginning with propylene, are present. Like results were obtained by Mendeléef [*] likewise from crystalline manganiferous cast iron, the oily liquid so obtained being " exactly similar to natural naphtha in taste, smell, and reaction ; " and on the decomposition of iron carbides by steam he has built an elaborate theory for the genesis of the great naphtha deposits of the world.

Whatever be the source of the natural naphthas or petroleums —whether they be attributed to the decomposition of organised matter or to the decomposition of iron carbides by steam—the fact that their artificial formation is due to but one method is the essential point. The only hydrocarbon formed synthetically from the union of the constituents previously existent in the free state is acetylene. But for economic purposes enormous quantities are manufactured from the products already provided by nature. In seeking, therefore, the rationale to explain the formation of hydro-carbons from iron carbide, it is well to first examine the effects produced by the destructive distillation of such substances as from their nature would be likely to throw light on the forma-tion of those hydrocarbons. The nature of the product and the conditions of formation, especially temperature, may then enable a clear interpretation to be put on the reactions taking place on treating iron carbide alloys with acid. Of the many organic com-pounds giving hydrocarbons on destructive distillation, coal, in the proportion in which it contains its reactive elements, is best suited for such examination. It presents large quantities of reactive carbon oxygen and hydrogen, and small bulk of nitrogen. Much the same relation exists in iron alloys under the conditions now dealt with. In both coal and iron alloys the resultant compounds

are to be distinguished by Mills' classification into "Products" and "Educts," according as they were present as such before reaction or were formed by reaction. It is to be added that such distillation is here viewed as a process in which all or nearly all of the resultant products are formed from elements present in the original compound, although the method of decomposition, whether by heat, acid, or steam, sometimes plays an important part in such products; that is, distillation of iron carbide alloys by acid and the distillation of coal by steam are viewed as analogous processes.

Heated with free access of air, the carbon of organic matter burns to carbon dioxide, and the oxygen and hydrogen form water. Subjected to destructive distillation, the products obtained are totally different, and, moreover, differ among themselves according to the temperature at which the distillation takes place. Mills[*] states that "at high temperatures carbon and carbonised gases of low illuminating power are formed with but little liquid distillate; at a low temperature there is much liquid product and gas of high illuminating power." At low temperatures along with the paraffins series are found the olefines, C_nH_{2n}. At higher temperatures the liquid and solid paraffins have disappeared, and methane represents the paraffin series accompanied by the olefines and hydrocarbons of the aromatic series. Furthermore this decomposition is not haphazard, although completeness of decomposition depends on temperature. Mills[†] finds considerable evidence in favour of the "definite character of the destructive distillation of coal and shale. It is probable that the organic matter in these minerals can always be represented with an nC_8 formula; . . . C_3 is the fundamental unit or stable condition in these effects; and not less than this unit must be removed from, or left in, the 'fixed carbon' during destructive distillation." Organic substances according to a simpler or more complex structure differ in the number and variety of their distillation products, but under like conditions give rise to many such products common to them all. Can now this reasoning be applied to the hydrocarbons obtained from iron carbide, and can their formation be considered as due to a process in some way

[*] "Destructive Distillation," p. 8.
[†] Fuel, 32–35; Mills and Rowan. Vol. i. of Groves and Thorpes' Chem. Tech.

analogous to a destructive distillation ?   It has been shown that, with but one exception, it is not possible to form the hydrocarbons directly from their constituent elements.   Hence the supposition that the nascent hydrogen acts upon carbon in any other form than nascent carbon set free from combination with some element or group of elements is improbable, and such action would be an instance of rare exception.   It can be accepted, therefore, that the hydrocarbons formed by the action of steam or acid on iron containing carbon is the result of a reaction involving the decomposition of a compound of carbon with iron.   Again, from the results of Cloez it appears that the nature and the quantity of the hydrocarbons so evolved is dependent on the amount of combined carbon in the iron alloy from which the gas is obtained, and that the hydrocarbons from ferro-manganese, in which the carbon is admittedly in a condition widely different from amorphous carbon or graphite, are greatly in excess of the quantity obtained from grey cast iron, in which the combined carbon is present in but comparatively small amount.   Also the nature of the hydrocarbons obtained from iron alloys treated with acid is similar to that obtained from the destructive distillation of coal, and, moreover, indicate a distillation at low temperature.   This is shown by the experiments of Cloez and of Mendeléef on ferro-manganese, the hydrocarbons formed being almost exclusively of the olefine series, C_nH_{2n}.*   Table IX., giving the analysis of the gas obtained by acid from white irons as represented by the manganese-tungsten alloys, of ferro-manganese, and of several different classes of iron and steel, all show the absence of the saturated hydro-carbons of the paraffin series and of the aromatic series, C_nH_{2n-6}.   But it has been shown by Cloez that the hydrocarbons obtained are by no means confined to one member of the unsaturated series, and, on the contrary, he succeeded in isolating several of the series from what he considers to be a mixture of many homologues, the boiling-point of the hydrocarbon mixture rising from 120° to 190°, at which point it was inadvisable to push the distillation any further on account of decomposition products.   As reaction between two compounds (capable of reaction) at definite tempera-

* The gas obtained by treating ferro-manganese with acid burns with an illuminating flame.

ture and pressure is usually a constant property, this formation of many compounds by the action of reagents on iron with carbon must be attributed either to changes of reaction affected by the conditions during solution, to secondary reactions, or to the decomposition of a number of iron carbides. Knowledge of the iron carbides is too limited to enable it to be stated in positive terms that combined carbon is limited to the carbon of cementite and hardening carbon, but it is as yet impossible to assign any definite formula to "hardening" carbon, and the simpler and therefore more generally accepted and acceptable theory is that it forms an indefinite solution compound with the iron. Perhaps all three influences are at work. The main point of this work and discussion is to show that there is stronger ground for attributing the formation of the hydrocarbons obtained from steel attacked by steam or acid to the analogous process of their formation from organic substances, than to attribute them to the action of nascent hydrogen acting on the element carbon in the uncombined non-nascent free state ; for the element carbon, it can be added, has never been found in nature, and isolated in any other form than that of diamond, so-called amorphous carbon or graphite—all highly polymerised forms. The element carbon as found in the vast series of organic compounds has never been isolated, and perhaps never can be isolated, except in these polymeric forms, in which it invariably appears whenever the organic compound is destroyed with separation of carbon. The element carbon, as known in its free state, and the elemental carbon, as combined with other elements, are two poles which as yet cannot be brought together.* And carbon is not at all exceptional in this respect, for just as little is known of the element iron or potassium as they exist in their salts. Metallic iron or metallic potassium, when isolated, must from their properties be widely different from their combined condition, and from these properties it can only be accepted as fact their great polymerisation in the metallic state, and their more or less complete dissociation in their salts and solutions ; and approach to completeness of dissociation is only found on great dilution. Such a point of dilution may be reached in very

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* From the researches of Moissan it is known that carbon passes from the solid to the gaseous state without showing any trace of the intermediate step of fusion. Gaseous carbon readily forms compounds with other elements present. *Bull. Soc. Chim.*, 1895, vol. xiii. p. 798.

low carbon iron, but the saturation-point of iron for carbon is so low, and the influence of "combined" carbon on iron so great, even in very small quantities, that practically in commercial iron carbide alloys the point of complete dissociation is rarely reached, if ever.   But it is difficult to view the form of carbon now under discussion—so called dissolved carbon—as dissociated, and, to carry the idea still further, ionised.   For all the peculiarities of hardened steel increase with the content of carbon.   If the homogeneousness found in high carbon quenched steel is to be attributed to dissociation, it affords an example the exact reverse of all known—ionisation increasing with concentration.*   The carbon, therefore, obtained as hydrocarbon must be some form of combined carbon, and the variety of the products calls for explanation.   The assumption of an elemental free carbon reacting with nascent hydrogen requires a not impossible but improbable reaction, one only observed under the influence of great heat. †

And this view of iron carbides and associated carbides can be still further emphasised.   In Table XII. will be found some experiments carried out on the line of Prost's experiments, and which bear on the relation existing between the elements present in the residues obtained on treating ferro-manganese with hydrochloric acid of varying strength, the relation existing between the carbons so obtained, and the application of Mill's law of "definite distillation" products.   In these experiments the quantity of alloy taken and the quantity of hydrochloric acid (of 1·19 specific gravity) used as solvent were constants, but the water added, i.e., dilution, varied from 0 to 400 c.c.   It is shown that Prost's results are not confined to white iron, but also in their general application are found with ferro-manganese.   A large portion of

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* Professor J. O. Arnold, *Bull. Soc. d'Enc. Ind. Nat.* (5) i. 97, describes high carbon quenched steel as practically homogeneous.   From mechanical and physical tests, and from the microstructure, he regards pure iron as saturated at 0·89 carbon.   In quenched steel of this percentage all the carbon is combined with all the iron in the form of sub-carbide, $Fe_{24}C$.   In quenched steel of lower carbon, metallic iron mixed with subcarbide is formed, whereas in quenched steel of higher carbon, the excess of carbon reacts with subcarbide to form Fe_3C, according to the reaction $Fe_{24}C + 7C = 8Fe_3C$.

† Note the difference between the composition of gas obtained by destructive distillation from bituminous coal and water or producer-gas ; reaction between hydrogen and carbon set free from combination and reaction between hydrogen and free carbon in the form of coke.

TABLE XII.—*Ferro-manganese B. Taken 20 Grammes of Metal. 100 C.C. Hydrochloric Acid of 1·19 Specific Gravity. Water, Variable. Action in the Cold. Metal in Powder.*

Elements.	1.	2.	3.	4.	5.	6.
Iron	0·0785	0·0677	0·1128	0·1349	0·1168	0·1761
Manganese	0·4156	0·2578	0·4910	0·5749	0·5962	0·6229
Silica *	0·1815	0·2047	0·0496	0·0342	0·0116	0·0366
Phosphorus	0·0193	0·0284	0·0109	0·0124	0·0071	0·0131
Carbon	0·3040	0·2424	0·1772	0·1782	0·1154	0·0478
Total volume of liquid acid solvent in C.C. . .	100	150	200	300	400	500
Per cent. of acid present .	38·73	29·05	19·37	12·58	9·68	7·75
Weight of residue from 20 grammes . . .	0·87	0·84	2·75 †	3·33	3·41†	2·26
Per cent. of residue . .	4·35	4·20	13·75	16·60	17·00	11·30

* Partly or wholly as silicon, as in 4, 5, and 6.

† Approximately : 1. Amorphous honeycombed granular masses of silica. Colour white, slightly greyish. 2. Amorphous honeycombed granules. White pumice-like silica intimately mixed with metallic granules of brassy colour. Sometimes both coalescing in the same fragment. 3. Amorphous honeycombed masses. Metallic, with steel blue or brassy lustre. No skeletons of silica present. 4. Amorphous honeycombed masses. Brassy and white metallic lustre. Silica, but in small quantity. 5. Granular metallic masses of steel blue or brassy lustre. No silica present. 6. As in 5. Silica present.

TABLE XIII.—*Iron Carbides. Variation in Carbon in same Sample. Taken N-Grammes of Alloy. 100 C.C. Sulphuric Acid of 1·82 Specific Gravity. Water, Variable. Action in the Cold.*

	Rail Steel.				Boiler Plate. Percentage of Carbon in Residue.		
Total volume of acid solvent in C.C. . .	500	700	900	1100	500	700	900
Number grammes of alloy taken . . .	7·85	7·68	9·48	9·97	...	...	...
Carbon dioxide obtained by combustion	0·0778	0·0885	0·1038	0·1206	0·5056	0·5720	0·5742
In ten grammes . .	0·0991	0·1152	0·1095	0·1210	...	...	...
Carbon	0·0270	0·0314	0·0299	0·0330	0·1379	0·1560	0·1566
Difference	0·0044	0·0015	0·0031		0·0181	0·0006	
Insoluble carbon in one gramme of sample .	0·0027	0·0031	0·0030	0·0033	0·0006	0·0009	0·0007

In the case of the boiler plate the figures in the third line of the table represent the percentage of carbon in the residues, and not the percentage based on the original alloy. The quantities taken, and the percentage of total alloy taken, that these residues represented, were, respectively (500), 24·5 grammes taken. Residue 0·47 per cent.; (700), 33·0 grammes taken. Residue, 0·57 per cent.; (900), 34·5 grammes taken. Residue, 0·48 per cent.

such residues evidently belong to the original alloy containing
iron, mainly as phosphide and manganese, and iron as carbide
and silicide, or as carbo-silicide.   The reaction nature, however,
even of these metallic compounds, is shown by the hydrogen and
oxygen found by Prost to be present in his white iron.   The
conditions in which such residues are obtained depend clearly on
the strength of the acid and the energy of the reaction.   With
dilute solutions on adding the ferro-manganese to the acid con-
tained in a beaker cooled externally with cold running water,
there was but little if any rise in temperature, whereas with
strong solutions even under these conditions, and on adding the
alloy in small portions at a time, much heat was developed.   This
had great influence on the condition of the silicon in these resi-
dues.   By the strong solutions this was present in part or
entirely as silica, whereas by the weak solutions often not a trace
of silica could be observed microscopically, and this is upheld by
the gradation found in passing from strong to weak solutions.
Carbon, silicon, and phosphorus diminish in the residues as the
solutions become more dilute.

But if variation in the strength of acid gives rise to any regular
order in the products evolved, such order is to be found in passing
from acid of one strength to another.   Professor Mills in his
paper * gives the results of an investigation extending not only
over coals but over a number of organic substances, and, as stated,
considers that the unit of carbon removed from or left in organic
substances subjected to destructive distillation is represented by
a C_3 group or some multiple of it, i.e., nC_3.   A general formula
cannot as yet be given to the iron carbides, and whether the
combined carbon can be represented by C_3 or some multiple of it
is undetermined.   It is more important, however, to establish
regularity without reference to the actual factor representing the
differences; and when the carbons obtained by variation in
strength of acid acting on this ferro-manganese, in which the
carbon is present as carbon evolved as hydrocarbon, even by
boiling water, are ranged in a series, it will be found that in
passing in order from one member of the series to the next

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* *Journal of the Society of Chemical Industry,* vol. iv. p. 325 (1885).   See also
R. Tervet, *Ibid.* vol. xiv. pp. 1028-30 (1895).

higher or lower, as the case may be, that such differences are related numerically.   For example, in Table XII. :—

1.		2.		3.		4.	
3040	—	2424	—	1772	—	1782	—
	0616	—	0652	—	......	—	......

2.		4.		5.		6.
(2424	—	1782)	—	1154	—	0478
—	0642	—	0628	—	0676	—

The agreement is sufficiently close as to be striking; and if there is no general rule of difference, analogous to that found in the decomposition of organic carbon compounds, the coincidence is unexpected.   With iron carbide sulphuric acid was substituted as solvent, as this acid when dilute is effective with such alloys in the cold.   With the sample of rail-steel examined, solution was complete in twenty-four hours, and a marked regularity found in passing between acids of varying strength.   The results obtained were not of the same order as found with ferro-manganese and hydrochloric acid, for with the iron carbides carbon increased with greater dilution of the acid, whereas with ferro-manganese the opposite was found to be the case.   With sulphuric acid of greater concentration than given in the table, action in the cold soon ceased, owing to formation of insoluble iron-salt.   In this action of acids on iron and associated carbides, the nature of the carbide may be an important condition; but this gradation found taken in connection with the analyses of the gases evolved on such solution is suggestive.

As the hydrocarbon constituents of the gases are evidently due to reaction between nascent hydrogen and carbon in the alloys in some form of combination, with iron or with other elements present, forming compounds in definite ratio, or combined by comparatively complex molecular aggregates, the question arises, Can carbonic oxide be attributed to a like or the same cause, or is it formed in secondary reactions between the evolved carbon compounds and the oxide or acid present?   Its formation from the hydrocarbons as such can be negatively answered, for hydrocarbons are extremely stable in the presence of dilute acid, and would enter into reaction forming more complex compounds, and not simpler.   The origin of carbonic oxide cannot, therefore, be attributed to decomposition of the hydrocarbon furnishing elemental carbon, but must be sought in other carbon compounds or in substitution products of the

hydrocarbons. The typical formula for the formation of hydro-
carbons by the action of steam on iron carbide is given by
Mendeléef * as—

$$3Fe_mC_n + 4mH_2O = mFe_3O_4 + C_{3n}H_{8m}.$$
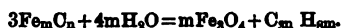
This formula, involving the formation of magnetic oxide, would
supply oxygen to the reaction for the formation of carbonic
oxide. Can this be assumed to be the case when sulphuric
acid in water solution is used to bring about the reaction? It
is doubtful. Unquestionably in some cases the reaction between
metal and acid is a very complex one, resulting in the forma-
tion of oxide or of decomposition products with the acid by
secondary reactions; as, for instance, with copper and sulphuric
acid.† But such has not been established for iron, and on the
contrary the reaction appears to be very direct. In place of
the above formula, therefore, in using sulphuric acid to decom-
pose the iron carbide, the simplest formula would be—

$$Fe_mC_n + mH_2SO_4 = mFeSO_4 + C_nH_{2m}, \text{ or } m=n, C_nH_{2n}$$

which is in accordance with the result of experimental investiga-
tion. Such a formula would fulfil all the requirements for the com-
bination of hydrogen and carbon, both being present in a nascent
condition owing to reaction. This would require the excess of
sulphuric acid to maintain its molecular condition in despite of the
various reactions resulting from its action on the heterogeneous
iron alloy. But it has been shown by Cailletet ‡ that even in
the action of pure dilute sulphuric acid on nearly pure iron, that
the resulting reaction is not confined to the replacement of
hydrogen by iron, but that a secondary reaction takes place
between the excess of iron and the nascent hydrogen, and that
iron so treated shows a marked alteration in its physical pro-
perties, due to absorbed, occluded, or combined hydrogen. The
directness of the replacement is therefore disturbed by secondary
reactions, and that such secondary reactions do occur is shown by
the variety of hydrocarbons obtained, due, it can reasonably be
assumed, to combination of hydrogen and carbon under varying

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* "Principles of Chemistry," vol. i. p. 365.
† Baskerville: *Journal of the American Chemical Society*, vol. xvii. p. 904. In the
reaction between iron and dilute sulphuric acid, however, reaction between Fe and H_2O
may take place, giving rise to a secondary reaction between the oxide so formed and the
acid.
‡ *Comptes Rendus de l'Académie des Sciences*, vol. lxxx. p. 319.

conditions, and not to the assumption of an indefinite number of decomposable carbides.   Of the constituents of commercial iron carbides, hydrogen is probably set free as such.   Phosphorus gives reactions somewhat more complex, for, in addition to the hydrogen compounds formed with nascent hydrogen, decomposition products are formed, as shown by the presence of oxides dissolved in the acid.   Sulphur is known to be present as hydrogen sulphide, unattacked sulphide, and organic sulphur. Its presence in this latter form has been shown by Prost,[*] who found it as "insoluble organic sulphur" in the residue left on dissolving cast iron in hydrochloric acid, and by Phillips,[†] who, in an examination of the evolution method for determining sulphur, showed it to be a difficultly oxidisable compound, "possibly a sulphur ether of the type $(CH_3)_2S$."   He detected it in the oil drops.   The undissolved residue from the treatment of the iron alloy by acid in the cold is a substance or substances complex in nature.   In addition to the metallic portion present, it contains carbon compounds due to reaction.   The very nature of these carbon compounds requiring the presence of moisture, the elements of water, for their formation, shows the complexity of the reactions to be studied in what ordinarily has been taken to be a comparatively simple reaction.   Under such conditions it is evident why Cloez found that the hydrocarbons obtained could account for but a portion of the combined carbon, for a considerable part of it is only expelled from the solution at a comparatively high temperature; carbon is present in the form of other organic compounds in the black residue, and in combination with oxygen to form carbonic oxide.

Can then the presence of carbonic oxide in the gases from the acid solution of iron and steel be attributed to reactions ? (1.) As stated, there is the residue left on dissolving the iron alloys in the cold with dilute hydrochloric acid.   This residue, to which attention was called by Proust (1799), was examined by Fremy, and found to contain hydrogen carbon and oxygen— the result of reaction between the aqueous solution of the acid and the hydrogen carbon compound formed by reaction between

* Fremy: *Comptes Rendus.*   Prost, as cited; volatile phosphorus he gives as phosphamine.   In the ternary alloys and ferro-manganeses A. and B. no phosphine was detected by silver sulphate solution.   Moissan: *Bulletin de la Société Chimique,* 1895, vol. xiii. p. 818.

† *Journal of the American Chemical Society,* vol. xvii. p. 891.

those elements set free in the nascent state from the iron alloy.
It is a distinctly reaction compound. It is not a stable com-
pound. Prost (*loc. cit.*) found that its composition varied with
the concentration of the acid, and also its bulk. It therefore
reacts. On heating the acid solution it disappears, and probably
forms, in part at least, the "hardening carbon" of Osmond and
Werth, which possesses like properties in nitric acid solution.
Fremy describes it as cyanohydrate, and in more recent investiga-
tion on carbide in iron the presence of this "hydrate of carbon"
as impurity is frequently referred to. Direct determination on
the residue from twenty grammes of ferro-manganese B. showed
the nitrogen to be but a minor constituent of this residue, and
probably due to cyanide of titanium, which Hogg * has shown to
be present in ferro-manganese. (2.) Reaction between the con-
tained oxide of the alloy placed under reducing conditions in
the presence of nascent carbon from the decomposition of the
carbides of iron or carbide of secondary and reaction formation.
(3.) The fact established by Moissan † that all the graphites
isolated from commercial iron contain, in addition to carbon, also
oxygen and hydrogen. Hence the presence of carbonic oxide in
the acid solution gases does not necessitate the presence of the CO
radical as such in iron or steel, whether as oxycarbide or as gas
dissolved in the metal or entangled in its pores. In cold-bored
metal Muller ‡ shows that carbonic oxide exists only in pig
metal, Bessemer and Martin metal before deoxidation, direct
Bessemer metal, and close steel of Bochum. He, however, ex-
plains its absence as being more closely combined with the iron
than hydrogen or nitrogen present. If, however, such were the
case, it is remarkable that on solution these oxycarbides are not
decomposed and their presence shown by marked increase of
carbonic oxide in the gas obtained by the acid solution method;
but, on the contrary, even on eliminating all hydrogen from the
gases so obtained, the carbonic oxide is but a minor constituent,
and if hydrogen in proportion to that found in the cold-bored
gases be added, it again sinks to trifling volume, readily attri-
butable to the nature of the metal from which it is obtained.
Given carbon capable of combination (nascent) in the presence

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* *Industries and Iron*, 1893.
† *Bulletin de la Société Chimique*, 1895, vol. xiii. p. 814.
‡ *Industries and Iron*, 1883, p. 115.

of a limited volume of oxygen, and under these severe reducing conditions, and the form of oxidation would be CO. Under such conditions carbonic oxide would appear in the gas although not present in the alloy before boring or solution. Heated in vacuo with oxide present, carbonic oxide would be readily formed in iron carbide alloys and appear in the gases, and its presence is so explained by Parry.* If the gas, then, be found in the gases obtained by cold boring, heating in vacuo, or on solution of the metal in acids, its formation by reaction can not only be shown to be possible, but, chemically considered, it would be surprising not to find it, and its presence as such in commercial iron carbides is to be regarded as very dubious.

The formation of nitride of iron, established by Despretz, was made the subject of an elaborate investigation by Fremy. This investigation, dealing with the reactions between nitrogen, nitrogen compounds, and iron, fully established the conditions of the combination of nitrogen and iron, and the chemical nature of the compound so formed.

That nitrogen is present in iron and steel is shown by the researches of Fremy, Boussingault, Stuart and Baker, and A. H. Allen. Boussingault † heated iron to a red heat in steam, distilled the alkaline solution, and titrated the distillate with acid. Stuart and Baker ‡ heated the iron to full red heat in hydrogen, absorbing the ammonia formed by sulphuric acid. They obtained by this method but trifling quantities of nitrogen. A. H. Allen § positively established the presence of nitride of iron in Bessemer metal. He also heated the metal to a red heat in a rapid current of steam. Under these conditions Bessemer metal and nitride of iron gave ammonia in such quantity as to be estimated by platinic chloride, whereas pure iron obtained by reduction by hydrogen gave none to Nessler's test. The evolution of ammonia from the Bessemer metal progressed regularly with the oxidation of the iron. Solution of the metal in hydrochloric acid and subsequent distillation gave like results. Zinc, nickel, and aluminium gave him no ammonia, and magnesium and sodium but little. Comparing his results with those obtained

* *Journal of the Iron and Steel Institute*, 1874, No. I. pp. 88-92.

† *Comptes Rendus*, 1861, vol. lii. pp. 1008, 1249 ; vol. liii. p. 77.

‡ *Journal of the Chemical Society, Transactions*, 1864, vol. xvii. p. 390.

§ *Journal of the Iron and Steel Institute*, 1880, No. I. p. 181.

by Stead* from cold-bored iron, Allen found chemically combined in steel 0·0170 per cent., and in cast iron 0·004 per cent. Stead found in steel 0·0173 per cent., and in cast iron 0·042 per cent. Howe† regards nitrogen as held by both chemical and physical attractions, and but feebly by their united strength. It can be added that the nitrogen obtained by the mechanical methods mentioned, viz., cold boring and heating in vacuo, is not to be ascribed to nitride of iron, for this salt has been shown by Fremy to be a compound of considerable stability. The decomposition of nitride or nitro-carbide by acid evolving hydrogen would result in the formation of ammonia dissolving in the acid solution to ammonium salt. The nitrogen, therefore, found in the analyses of gases obtained from iron must be present in the metal either mechanically entangled in the pores or in a condition to be classed as physical mixture, separated by changing the physical texture of the iron by solution, and hence releasing the gas. The agreement as to volume obtained by different methods points strongly to the mechanical theory, for cold-bored iron would give but little nitrogen held in physical mixture.

Eliminating hydrogen (Table IX.) from the composition of the gases evolved on treating iron with acid, in nearly every case the residual gas or "nitrogen" makes up three-fourths of the total volume, and even in the original gas as evolved, although diluted with hydrogen from inter-action of acid and metal, a considerable percentage of the gas volume is inert to all the absorbents of gas analysis, and does not combine with oxygen on explosion. This negative evidence is so strong as to be proof in itself that the residual gas is nitrogen, or possibly containing inert gas recently discovered.‡ Without attempting to ascertain the absence or presence of such gases, it was therefore sought to establish in some positive way the presence of nitrogen in the gas residue obtained after removal of other constituents by absorbents or sparking. Several alloys showing marked percentages of residual gas were selected for analysis. In most cases the proportion of hydrogen to residual gas was as 4:1. The gases absorbable by reagents were removed as described,

* Cited by Müller: *Industries and Iron*, 1883, p. 115.
† "Metallurgy of Steel," p. 107.
‡ Two years ago the composition of such a gas would be set down as "nitrogen," especially after obtaining positive reactions of that element in its oxygen and hydrogen compounds. Given, however, the results of the great investigation carried out jointly

except carbonic oxide. To the mixture of hydrogen, carbonic oxide, and residual gas, pure oxygen was added in slight excess of the quantity necessary to form water and carbon dioxide. The mixture was then exploded, the carbon dioxide absorbed by potash, and the gas passed back again to the explosion pipette. Sixty c.c. of pure oxygen were added (a large excess), and two c.c. of tested water was passed from the burette into the pipette. The gas mixture was then sparked for ninety minutes and the water in the pipette collected for examination. Its reaction was intensely acid to litmus, it gave a deep blue colour to diphenylamine in sulphuric acid solution, and a deep red colour with brucine. Distilled in alkaline solution (caustic soda tested) with addition of aluminium (tested), the distillate gave in the first 50 c.c. a deep brown colour to Nessler's test, rapidly forming a precipitate. The ammonia obtained from the third 50 c.c. was too large to read for colour test. Again the purified residual gas was sparked as before. The water collected was distilled from alkaline solution containing aluminium, and the distillate passed into a flask containing pure, ammonia free, hydrochloric acid. This solution was evaporated with platinic chloride solution and the characteristic yellow salt obtained. All the reagents used were specially prepared, and before distilling for ammonia the distilled water and caustic soda were partially distilled and tested by Nessler's test to ensure absence of ammonia. Blank tests were carried out with the analysis. The aluminium was examined for nitrogen forming ammonia with nascent hydrogen. It can, therefore, be accepted that the residual gas contained a considerable quantity of nitrogen, and that on solution in acid iron sets free nitrogen in at least two forms—as ammonium salt in the acid solution, and as nitrogen gas in the gaseous mixture evolved.

The existence of a definite compound of nitrogen and iron—nitride of iron—was proved by the synthetic experiments of Fremy * (1861). He effected the union of nitrogen with iron by

by the eminent English physicist and chemist, the possible and even probable presence of other inert gases is to be considered. The same uncertainty, however, exists in returning "iron" or "copper," &c., in an analysis, for at some future day means may be found to decompose these so-called elements. This uncertainty as to our present elements is emphasised in every treatise dealing with chemical theory, and is perfectly understood.

* *Comptes Rendus*, vol. lii. pp. 321, 415, 616, 718, 909, 1162. His experiments were largely directed to support his cyanide theory of cementation and the presence in steel

a number of methods, the compounds so formed showing no differences.   Direct examination for hydrogen with negative results showed the absence of amide.   Pure nitride contained 9·3 per cent. nitrogen, corresponding to the formula Fe_5N, and practically identical with the " Siderazot " found later by Silvestri in the lavas of Etna.[*]   In chemical properties the nitride showed fixation of the nitrogen.   It was less oxidisable than pure iron.   Nitric acid attacked it but slowly, hydrochloric and sulphuric acids readily forming iron and ammonium salts.   It stood red heat without decomposition, and oxygen only attacked it at high temperatures.   Heated with carbon or in a carbon crucible, it was decomposed, giving a mass that hardened and tempered like steel, and which when heated in hydrogen gave but traces of ammonia, whereas the original nitride gave at once ammonia and pure iron.[†]   Mene,[‡] following Fremy's experiments, obtained in a burnt iron 1·61 per cent. nitrogen, and concluded that it contained nitride as well as silicide.   Moreover, after heating in hydrogen, on dissolving in acid he found ammonia ; and the ammonia obtained by dissolving in hydrochloric acid, sulphuric acid, or iodine, did not give concordant results on the same sample.   The variations he attributed to atmospheric contamination.

Fremy's results are most important as to the form in which nitrogen exists in iron alloys.   As stated, from the examination of the gas obtained by dissolving iron in acid and of the acid solution there are at least two forms of nitrogen present.   One form readily enters into combination with nascent hydrogen ; the other is evolved as nitrogen, inert, and only entering into combination with other elements slowly and under special conditions. This latter presents some difficulties as to its origin.   It may possibly come from chemical compounds evolving nitrogen gas on decomposition, and represent the surplus which escapes before opportunity for reaction has been afforded ; or, more probably, it can be nitrogen as such held mechanically in the pores of the metal, originally derived from the air, and showing the greater chemical affinity and absorptive power of the metal for the oxygen constituent ; or it can be nitrogen held in solution in the

of carbonitride.   See on this subject paper of Caron, *Comptes Rendus*, vol. lii. pp. 635, 1246, and others.

[*]   *Poggendorf's Annalen*, vol. 157-169.   It had metallic lustre.   Specific gravity, 3·147. Non-magnetic.   Contained Fe=90·86N=9·14.   Eruption of 1874.

[†] *Comptes Rendus*, vol. lii. p. 322.   [‡] *Ibid.*, vol. lii. p. 1193.

iron in a form more nearly approaching physical mixture than chemical combination. Its effects under such conditions would affect the mechanical properties of the metal, and would have but little place in a discussion of the chemistry of iron alloys. The nitrogen forming ammonia, and so remaining in the acid solution, may exist in the iron in a variety of forms—as cyanide, as ammonia, as nitro-carbide, or as nitride of iron. (1.) If a carbon nitrogen compound, the cyanogen form would appear to be the most natural to attribute it to, and Hogg * has shown that such compounds are widely distributed throughout the structure of ferro-manganese; but Shimer † in his first paper, and again recently, has shown that these cyanides are not attacked by acid. It can be added that no cyanogen was found in the gases evolved on treating the iron alloys with acid, in the confining water of the burette, or by the proximate analysis, as shown in Table XI. Pure potassium cyanide, after continued boiling with dilute sulphuric acid, on distillation from alkaline solution, did not react with Nessler's solution or give yellow salt with platinic chloride (taken one gramme of cyanide). Hence, if cyanides remained in the acid solution, and were not evolved as such on account of the diluteness of the acid, they cannot account for the ammonia that is unquestionably obtained by distillation. (2.) That ammonia is evolved from hot iron or steel has been established by a number of observers,‡ and its formation from the combined nitrogen and hydrogen under such conditions is readily understood. Its presence is to be attributed entirely to reaction, for its existence as such in iron is difficult to conceive in view of the action of ammonia on iron, as shown by Fremy. (3.) To a nitro-carbide Fremy attributed the peculiar hardening power of steel. His experiments involve the chemical *rôle* played by nitrogen during the formation of iron carbides.

At that time Caron showed that steeling (acieration) was possible without the presence of nitrogen, which, however, in commercial practice probably was an important agent through formation of cyanide and subsequent decomposition, thereby pre-

* *Industries and Iron*, September 22, 1893.

† *Transactions of the American Institute of Mining Engineers*, 1886. Recently " On Determination of Graphite in Pig Iron." *Journal of the American Chemical Society*, vol. xvii., 1893.

‡ Cited by Howe, "Metallurgy of Steel:" Regnard, Barré, Forsyth, Emmerton, Goetz.

senting nascent carbon to the iron for absorption.   This view accepted the function of cyanides in the carburising process, but rejected the presence of nitro-carbide in steel as the hardening constituent.   In iron or steel the nitrogen forms such a trifling part of the sum total that action by cyanides is the more reasonable explanation of the experiment, and Fremy himself [*] appears to regard the "carbo-nitride" present as a residuum of that originally present and permeating the iron, the nitrogen being removed by hydrogen present, and leaving the metal more porous and permeable to excess of carbon.   Recent investigation bases the explanation of the hardening property of steel on very different grounds than as indicated above, but the question of the absorption of carbon by iron, especially in the cementation process, still remains for their application.   As to whether the small quantity of combined nitrogen found in steel is present as undecomposed nitro-carbide or as nitride, it is difficult to answer, but if as nitrocarbide, the absence of cyanogen on decomposition with acid is unexpected.   Fremy's experiment, by decomposing in oxygen and collecting the products, does not answer this question; but as iron nitride gives all the reactions affording ammonia, and as this applies to the nitride obtained from ferrous chloride, the simpler form is best for provisional acceptance.   The relation as to volume between the nitrogen gas obtained on acid solution and the gas obtained from cold bored iron is against the former, as being a decomposition product, and hence only escaping conversion to ammonia by its rapidity of evolution.

CONCLUSION.

Reviewing the results of the chemical analysis of the groups of iron carbide alloys studied, it is thought that the nature of these alloys can be stated in the following terms.   That liquid iron does not differ as a solvent from other liquids; for example, water, except in the comparatively great complexity of its molecular structure.   On the cooling of such a mass containing in combination with it other elements, according to the conditions of such cooling and the volume and chemical affinity (for the solvent) of such elements, the solidified mass would present a structure homogeneous throughout, through intermediate forms, to

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[*] *Comptes Rendus*, vol. lii. p. 630; Caron, *ibid.*, more particularly pp. 635, 1246.

a highly segregated and crystalline condition in which a number
of definite compounds have been formed.   Such definite com-
pounds in iron are present in two forms: (1.) Compounds common
to alloys of wide range of composition, Fe3C, and the prismatic
forms found in manganese and chromium carbides, phosphides,
and sulphides; (2.) Compounds varying in composition from one
alloy to another, and dependent within narrow limits on the
conditions of cooling, and often on the immediately surrounding
magma from which the constituents are drawn.   Such are the
granular residues, differing only in degree from the ground-mass
of the alloy.   With the ground-mass of the alloy, directly com-
parable with vitreous structure of basalts, there is found a regular
gradation in iron alloys, and they are to be classed according to
the amount of differentiation undergone.   Iron carbides tend to
form homogeneous masses in which definite compounds are of
minor importance, the great bulk of the alloy entering into the
ground-mass.   Rapid cooling preserves this structure.   Slow
cooling promotes crystallisation.   Owing to its tendency to form
ground-mass, iron carbides are more subject to control even in the
presence of elements with which it forms inert compounds—if
present in small quantity, limits of homogenity are comparatively
wide.   To a considerable extent this is also the case with ferro-
manganese, but definite compounds (of form 1) take on a more
regular form, and the granular masses form a considerable per-
centage of the total mass.   In carbide with the sixth family—
tungsten, molybdenum, and chromium — definite crystallised
compounds are an important factor, and the dominant influence
of the added element is shown in the chemical inertia of the
granular residue sharply differentiating them from the soluble
portion to an extent not found in iron carbide or ferro-manganese,
in which the separation chemically from the ground-mass is not
marked.   Such elements, when present in large quantity, are
forming less capable of control. Although manganese and tungsten
form a ternary carbide with iron, the chemical properties of the
manganese, when present in sufficient quantity, class the resul-
tant product in its reactions with ferro-manganese.   If tungsten
is present in large proportion as compared with manganese, the
latter is not present in important quantities.   This refers to
large proportions.   In small quantities their action should be
almost independent of each other.

In examining the proximate analysis of the alloys given in the tables, it will be found that outside of phosphorus, carbon, and silicon present presumably in combination with iron, a considerable portion of these elements are present in a readily soluble form, and they are here attributed to the ground-mass of the alloy. Having, then, to deal with a complex substance of this nature, it has been attempted to show that the reaction which takes place on dissolving iron carbide alloys in acid is analogous to the process which takes place when an organic substance is subjected by steam to destructive distillation, and that the resultant products are what would be expected under such conditions showing variation in the hydrocarbon products (Cloez and Mendeléef), variation in the form in which the original constituents are evolved (Prost and Phillips), and variation according to the nature and strength of the acid used (Prost). The resultant compounds are mainly products, not educts, and from the constitution of iron alloys consist mainly of hydrocarbons and carbon compounds and small quantities of nitrogen, sulphur, and phosphorus compounds. The products of reaction differ only in degree from such products as are obtained in similar manner from organic carbon compounds, and no more than such compounds differ among themselves. From the simpler structure of the iron carbide alloys the resulting products are simpler in nature, less numerous, and contain a considerably less quantity of nitrogenous or oxygenated bodies. The assumption therefore of a large number of compounds differing in reaction to reagents is unnecessary.

CORRESPONDENCE.

Mr. R. A. HADFIELD, Member of Council, said that it was with much pleasure that he had accepted their Secretary's invitation to send a contribution to the discussion on the very valuable paper of M. de Benneville. That gentleman's experiments and conclusions so strongly supported the views of those who were unable to accept the allotropic theory relating to the hardening of iron, that, as one of those, he warmly welcomed the many facts elaborated at such length and so clearly by M. de Benneville. The latter's views only went to confirm more strongly those he had held on

the importance of those interested in the chemical side of metal-lurgical research, following up and improving their knowledge as to the conditions in which carbides of iron existed. There were also two very important points brought out in that paper, and which for several reasons should be of considerable service in enabling them to understand the behaviour of such a material as non-magnetic manganese steel. M. de Benneville clearly proved on page 230 that the prismatic carbide of iron or double carbide of iron and manganese was non-magnetic; that therefore went a long way towards explaining the non-magnetic character of manganese steel, that was, a steel containing 12 to 14 per cent. Mn. and 1 per cent. C. Of course it was not pretended that even such a masterly paper as that of M. de Benneville had solved the question of the carbide formation. The subject was one of the greatest complexity, but it seemed to him that M. de Benneville had gone far beyond previous workers, and they owed him a considerable debt of gratitude for the masterly way in which he had handled a subject so complex. It was to be hoped that it would be an encouragement to those who had for no little time, and often against powerful opposition, supported the belief that to properly understand the hardening of steel they must attack the question by means of the study, principally chemical, of the iron carbides, and to the aid of which had now come the study of its micro-scopical structure.

As regarded the summaries of Fremy's experiments given in the paper, it was not quite clear to what class of product reference was made under the head of clause "A" in section No. 3. He himself did not think that pure iron and carbon melted together in the proportion named (assuming that cast iron was referred to) would give other than a hard product; if it were grey and soft that would be owing to the presence of silicon, and that was quite apart from the presence or absence of nitrogenous matter. If it were possible to produce a grey cast iron in the absence of silicon he would be glad to have information, that was, a natural cast mixture. He did not think it was possible. In conclusion, he considered the Institute was under a special debt of gratitude to M. de Benneville for his admirable and suggestive paper. He trusted M. de Benne-ville would continue his work in the same direction, and if he could take up on the same lines various alloys of steel, including

manganese steel, he should be very happy to furnish him with a variety of specimens upon which to work.

Mr. E. H. SANITER noted that reference was made by the author to the nitrogen evolved from iron as possibly containing argon or helium. In that connection he thought it would be of interest to state that in June 1895 he collected the gases evolved on boiling powdered 80 per cent. ferro-manganese with water, and analysed them with the following results :—

	By Volume. Per Cent.
Hydrocarbon gases	6·6
Hydrogen	73·4
Nitrogen, &c.	20·0

After sparking the nitrogen, &c., in presence of oxygen and alkali for twenty-four hours, and absorbing the excess of oxygen, a residue was left of 2½ per cent. presumably of argon or helium. There was therefore present 17·5 per cent. of nitrogen, and 2·5 per cent. of argon or helium.

Mr. J. E. STEAD, Member of Council, wrote that it was with very great pleasure that he gave his testimony in commendation of the very excellent paper of M. de Benneville. The amount of work shown was of a colossal character, and it was only an analyst himself who could thoroughly appreciate the time and care which had been necessary to obtain the information which had been laid before the Institute so generously. Almost the whole of the paper consisted of original matter, and the results were of very great scientific interest. Personally he had not practically studied the nature of the carbides of manganese and tungsten, but he had obtained some very excellent brilliant scales of carbide of manganese and iron from a sample of Hadfield's manganese steel. The following were the results of the analyses of the steel and the carbide :—

	Steel. Per Cent.	Carbide. Per Cent.
Iron	85·80	72·00
Manganese	12·18	16·00
Carbon	1·77	6·85
Not determined	0·25	5·15

It would appear that the carbide was not pure, but contained a considerable quantity of water of hydration, and it was

evidently difficult to obtain these carbides from manganese steels without loss and partial decomposition. The remarks of the author relating to the nature of the carbon in iron were very interesting, and pointed directly to the conclusion that, if hydrocarbons were formed on treating metals containing carbon with hydracids, the metal must be in chemical union with the carbon, and he perfectly agreed with the statement of M. Benneville when he said, " It can be accepted, therefore, that the hydrocarbons formed by the action of steam or acid on iron containing carbon is the result of a reaction involving the decomposition of a compound of carbon with iron."

The other statement, however, in which the author discussed the formula of so-called " hardening carbon," that it formed an indefinite solution compound with the iron, was not quite so clear, but the sentence following made his meaning evident. " The main point of this work and discussion is to show that there is stronger ground for attributing the formation of the hydrocarbons obtained from steel attacked by steam or acid to the analogous process of their formation from organic substances, than to attribute them to the action of nascent hydrogen acting on the element carbon in the uncombined non-nascent free state; for the element carbon, it can be added, has never been found in nature and isolated in any other form than that of diamond, so-called amorphous carbon or graphite—all highly polymerised forms." When it was known that all hardened steels, excepting in such abnormal specimens which contained free graphite, on treatment with acid gave off all their carbon in hydrocarbons, it was possible to be quite satisfied in concluding that the carbon in such hardened steels must be in some definite combination with the iron, but whether or not it formed exceedingly attenuated carbides with the whole mass, or of some definite more highly basic carbide diffused throughout the greater mass of iron, remained yet to be demonstrated. Rich ferro-manganese, containing 83 per cent. and more of manganese, on coming into contact with water, decomposed with great rapidity. The water was decomposed, and gases of an illuminating character very rich in hydrocarbons was the result. He had seen several tons of ferro-manganese in wet weather burning in the open air. The second part of the paper treating on the gases present in iron

was most interesting and instructive, and he believed it was quite a discovery that there was free nitrogen in the gases evolved by treating iron and steel with acid.

Mr. JOHN PARRY thought that the author appeared to have achieved some considerable success in his attempts to isolate the iron carbides, alloys, and possibly also other combinations, which were now proved by the microscope to be present in the heterogeneous mass termed steel. He himself was firmly of opinion that in the near future an approximate analysis of steel based "at least for the present" on the methods given, would become an absolute necessity.

The study of those amounts together with those of ordinary elementary analysis, taking into consideration the atomic volumes and percentage weights, must, in due course, greatly extend their knowledge, and might modify the views they then held with respect to the causes regulating the physical qualities of iron and steel.

M. de Benneville's views in regard to the solution of foreign bodies in molten steel, which could be compared with the solution of salts in water, should meet with approval, and on the whole appeared to be correct, as also his remarks on the similarity of solidified iron or steel to a high rocky mass made up of definite compounds. From that it was evident that the first step in the approximate analysis of crude iron or steel should be the determination of what the author termed the "ground mass," analogous in nature to the vitreous portion of some volcanic rocks, that varying with the nature of the alloy. Relatively correct results might at least be obtained by using always the same quantity of solvent—a given weight of metal or alloy, under like conditions of temperature, time, and even granulation or fineness of metal.

Judging from some preliminary experiments, the most suitable seemed either acid potassium chromate, or an aqueous solution of bromide or very dilute nitric acid. There were, however, other solvents.

M. de Benneville's paper also contained much valuable additional matter touching the gases involved from steel, both naturally occluded gases and gases given off by special processes; the sources of these gases, whether by reaction or otherwise, being

matters which must be passed over for the present. The author, however, seemed to attach much importance to nitrogen as a constituent of steel, and therein differed somewhat from him (Mr. Parry), whose previous work showed the contrary. It was well known that he (Mr. Parry) regarded hydrogen as a most important constituent, and that he still thought further research in that direction would prove of service. Dealing with the absorption or occlusion of metallic and non-metallic vapours by iron, M. de Benneville noted Parry's observations that sulphur, phosphorus, or arsenic vapour, although readily absorbed by heated iron, were not—as with zinc, cadmium, &c. vapour—evolved on reheating. M. de Benneville attached some importance to that, and with good reason, for if that criticism could be maintained, proximate analysis afforded the only method of classifying the mode of combination. In that connection Professor Roberts-Austen's valuable contribution on the diffusion of carbon in iron, also generally on the diffusion of solids into each other, showed conclusively that even in the solid state, at comparatively low temperature, elements combined or diffused into each other, and that neither element need be in the form of a vapour or gas as usually understood. That might well be, for the absolute solid (except perhaps in the atom) did not really exist; no line of demarcation could be drawn between gases, liquids, or so-called solids; and the rate or intensity of chemical combination, occlusion, or diffusion (they could not be differentiated) was simply one of degree conditioned by temperature and by the relative density, affinity, and volatility of the substances in contact. In *Nature*, April 1893, the following appeared:—" It is now, we think, generally admitted that no element can be said to be *perfectly* stable even at low temperature when freely exposed in space; and it is possible that even bodies such as iron or carbon are slowly dissociating at ordinary temperatures, very much as water evaporates. The quantity of matter thus vaporised must be very small, may even be beyond the limit of our senses; yet if it is so, it affords a probable explanation of the diffusion of solids into each other, for it is evident that any mass or mixed masses of matter exist in an atmosphere formed by slow dissociation. The conception of the interpenetration of iron by carbon or any other body is thus rendered more easy."

OBITUARY.

WILLIAM JOHN BIRD CLERKE, C.I.E., died on February 13, 1896, at the age of fifty-eight. Mr. Clerke, who at the time of his death was an inspecting engineer under the Local Government Board, was educated at Trinity College, Dublin, where he graduated with distinction. After some years' work at his profession in Ireland he joined the Public Works Department under the Government of Bombay, and was employed for many years as an executive engineer in the Irrigation Department. In the great famine of 1876-7 the engineers had to find employment for large masses of unskilled and inexperienced workmen, and it was due, in a great measure, to Mr. Clerke's powers of organisation that under these conditions many large irrigation works of permanent utility were planned and completed in the Poona district. When the Bombay Municipality decided to settle the question of the water-supply of the city by the construction of a huge reservoir known as the Tansa Lake, he was appointed to carry out the work, with which his name will be permanently associated. The lake was formally inaugurated by the Viceroy of India in April 1892, Mr. Clerke being created a Commander of the Order of the Indian Empire in recognition of his services. He then closed his career in the East, leaving behind him a singularly high official reputation. He esteemed himself fortunate in securing employment under the Local Government Board, instead of having, like the majority of retired Anglo-Indians, to rest in idleness.

He was a Member of the Institution of Civil Engineers, and was elected a member of the Iron and Steel Institute in 1888.

GEORGE BOND died suddenly on April 22, 1896, whilst on a visit to Tapton Hall, a place not far distant from his residence, Brimington Hall, near Chesterfield. Descendant of an old Staffordshire family, he was born in 1841, and began his professional career in the mercantile marine. Before holding the position of general manager of the Staveley Coal and Iron Company, he acted as traveller for them, and on the death of

Mr. Charles Markham he assumed the charge of the gigantic concern, whose affairs he conducted so successfully. Recently he was placed upon the Commission of the Peace for the county. He was a Member of the Institution of Civil Engineers, and was elected a member of the Iron and Steel Institute in 1888.

ARTHUR BRÅKENHJELM, of Stockholm, died on January 18, 1896, in Worcester, Massachusetts. Born in Stockholm only twenty-three years ago, he was the son of the Governor of the province of Stockholm, and originally intended to enter the Swedish army. With that object in view, he was educated at the Royal Military Academy at Karlberg; but, after having been attached as a volunteer to the Royal Horse Guards, he was obliged, on the advice of his physician, to decline a commission in that regiment. He then spent several months in practical work at the Domnarfvet Ironworks, the property of the great company (Stora Kopparbergs Bergslags Aktiebolag) of which his father was chairman. He then studied at the Schools of Mines at Freiberg in Saxony, at Paris, and at London. He returned to Sweden in October 1895 to be married, and two weeks after his marriage he proceeded to the United States accompanied by his bride, with a view to studying the iron and steel industries of that country. He began his distressingly brief career in the United States as chemist to the Washburn and Moen Manufacturing Company's Siemens-Martin Works at Worcester. He was elected a member of the Iron and Steel Institute in 1895.

AUBREY BROCK died on November 28, 1895, at Mentone, after a brief illness. Born at Swansea in 1842, he was educated at the Swansea Grammar School, and at University College, London. He subsequently studied in Germany, and the knowledge of chemistry he acquired there proved of great value to him when, in 1879, he entered his father's business; his father, Mr. G. B. Brock, having, on the death of Mr. Nicholas Bowen, become sole owner of the firm of N. B. Allen & Co., Dinas Silica Brick manufacturers, of Hirwain and Neath, Glamorganshire, and of 110 Cannon Street, London. Mr. Brock was elected a member of the Iron and Steel Institute in 1880.

CLEMENT CROWTHER died on January 17, 1896, at his residence, Greenhill, Kidderminster, at the age of sixty-one. He was very well known in the Midland iron trade, and was chairman of Knight and Crowther (Limited), having some years ago sold the businesses of

which he was proprietor at Stour Vale, Falling Sands, and the Cookley Ironworks, Brockmoor, to that Company. He also traded as the Central Iron, Steel, and Tinplate Company, with offices in Church Street, Kidderminster, and was interested in other important commercial undertakings. He was elected a member of the Iron and Steel Institute in 1875.

ABRAHAM DAVY died at his residence, the Oaks, Pitsmoor, Sheffield, on January 25, 1896, in his sixty-sixth year. He was the eldest son of Mr. Joseph Davy, one of the founders of Messrs. Davy Brothers, Park Ironworks, Sheffield. At an early age he entered the business, and was actively connected with the management until his retirement a few years ago. He was also connected with the coal trade, being a director in Messrs. J. & G. Wells, Eckington Collieries, and Henry Briggs, Son, & Co., Limited, Whitwood Collieries. He was elected a member of the Iron and Steel Institute in 1883.

JOHN WILLIAM DEAN died on February 25, 1896. Born on February 9, 1844, he was trained as a civil engineer as a pupil of the late Henry Robertson, having served his time during the construction of the Central Wales Railway. He subsequently became engaged in railway contracting, and became a partner with the late George Meakin, and afterwards with his sons George and John Meakin. Among the works carried out by the firm of Meakin & Dean were the following:—

Doubling the London and North-Western Railway main line at Watford, including the new tunnel; making the new tunnel through Primrose Hill for the London and North-Western Railway main line; making tunnel through Primrose Hill (Belsize) for the Midland Railway; extending the London and North-Western Railway to Northampton, including the deep cutting at Roade; the Bala and Festiniog Railway; Alnwick and Cornhill Branch of the North-Eastern Railway; Wirral Railway; and portions of the Wrexham Molo and Connahs Quay Railway; and also work for the Rhymney and Great Western Railways.

Mr. Dean was managing director of the Minera Lime Company, Limited; chairman and managing director of the Broughton and Plas Power Coal Company, Limited; and chairman of the Brymbo Steel Company, Limited. He was also a director of the Vale of Llangollen Railway Company. He was elected a member of the Iron and Steel Institute in 1895.

HUGO HANIEL died on January 5, 1896, after a long illness borne with great patience. Son of the late Louis Haniel, who died in 1889, and member of a family whose name is prominent in the history of the industrial development of the Lower Rhine and Westphalia, he was born on May 25, 1854, at Sterkrade. After having been educated at the Ruhrort Realgymnasium, he devoted himself to the study of engineering from 1874 to 1877 at the Hanover Technical High School, and, after having fulfilled his military duties, was engaged from 1878 to 1880 in German and foreign metallurgical works. In 1880 he entered the firm of Haniel & Lueg of Düsseldorf-Grafenberg, and exhibited great skill and knowledge in the direction of that important undertaking. He was a member of the directorate of the Gutehoffnung Ironworks at Oberhausen, the Hohenzollern Works at Düsseldorf, and the Zollverein, Rheinpreussen, Neumühl, and Fröhliche Morgensonne Collieries. On all these boards his clear insight, careful judgment, and constant solicitude for the welfare of the works and the workmen, were highly valued. He was elected a member of the Iron and Steel Institute in 1888, and during the American meeting in 1890, and the Darlington meeting in 1893, made many friends among the English members. A portrait of Mr. Haniel with a lengthy obituary notice was published in *Stahl und Eisen,* vol. xvi. p. 227.

JOHN THEWLIS JOHNSON died at his residence, near Ambergate, on January 15, 1896, at the age of fifty-nine. He was the head of the firm of Richard Johnson & Nephews, who have long carried on a large business as wire manufacturers at Bradford, Manchester, and at Ambergate. He had been for fourteen years, and was at the time of his death, a director of the Manchester Chamber of Commerce, of which institution he was president in 1892. He was also a director of Nettlefolds (Limited), Birmingham. Son of Mr. Thomas Filde Johnson, Pendleton, who was a cotton-spinner at Bolton, in his early business life he was trained for the cotton-spinning industry. Later, however, he joined the wire-manufacturing firm founded by his uncle, Mr. Richard Johnson, on whose death, in 1881, he succeeded to the control of the works at Bradford and at Ambergate. He was elected a member of the Iron and Steel Institute in 1871.

HENRY MIDDLEMORE LYNAM died at his residence, Hart's Hill, Stoke-on-Trent, on November 4, 1895, at the early age of thirty-one.

Son of Mr. Charles Lynam, F.S.A., of Stoke-on-Trent, he was educated at Shelton and at King William's College in the Isle of Man.   He left school in his sixteenth year to enter the office of the late Mr. F. Wragge, manager of the Shelton Works and Collieries. Here he remained until the death of Mr. Wragge, when he was appointed secretary to the Shelton Company, and in 1891 was promoted to the office of general manager, which he retained until his death. Besides being a devoted man of business, Mr. Lynam took great interest in educational matters, and at the time of his death he occupied the position of deputy-chairman of the Hanley School Board. He was elected a member of the Iron and Steel Institute in 1894.

OCTAVIUS VAUGHAN MORGAN died at his residence, The Boltons, South Kensington, on February 26, 1896, at the age of fifty-nine. He was one of the younger members of the firm of Morgan Brothers, by whom the weekly journal the *Ironmonger* was founded in 1859. Messrs. Morgan Brothers were at that time carrying on a large business as ironmongers' sundriesmen in the city, and they also founded a crucible manufactory at Battersea.   For many years Mr. O. V. Morgan took a most active part in the management of the latter business, and on its behalf he made numerous journeys to India, China, Australia, and America.   Few men had a more thorough acquaintance with the condition of the British colonies.   At Battersea he had always taken an active interest in all social, philanthropic, and religious movements; and when it became a Parliamentary borough he was unanimously adopted by the Liberal party as their candidate.   He was opposed by Mr. J. E. Cooke, but won the election by a majority of 712.   At the general election in 1886 he held the seat against Mr. Cooper Willis, but by the reduced majority of 186.   He remained in Parliament until the general election of 1892, when he was defeated at Ashton-under-Lyne, which borough he contested, having found the strain of a Metropolitan constituency too severe.   He became seriously ill last autumn, and a long stay at Brighton failed to restore him.   He was elected a member of the Iron and Steel Institute in 1894.

WALTER NEILSON died on April 17, 1896, at his residence at Gourock.   The second son of the late William Neilson of the Mossend Ironworks, he was in early life one of the moving spirits in connection with those works.   After the amalgamation of the Summerlee and Mossend Works he carried on business on his own account, and in

1886 floated and successfully carried on the Clydebridge Steelworks, of which he was managing director. He was elected a member of the Iron and Steel Institute in 1880.

JOHN THOMAS NORTH died suddenly at his offices in Gracechurch Street, London, on May 5, 1896. Born in 1842, a solid, sturdy Yorkshireman, shrewd, honest, and quick, with no book-learning or accidental advantages of fortune, patronage, or friends, but with indomitable courage and energy, North was at an early age, whilst yet an apprentice in Fowler's workshops at Leeds, selected from his fellows to go out to Peru to superintend the erection and working of certain machinery. He at once set to work to make the most of his knowledge and the best of his time and wits in a strange land. One of his earliest enterprises was the condensing of sea-water for domestic purposes at a place on the coast north of Valparaiso, where rain never falls. Patching up an old iron steamer that had been wrecked on a reef, he converted her into a floating water-tank, and made a good profit by her. Other enterprises succeeded quite as well, notably the working of large guano deposits, and eventually he went back to England the possessor of great wealth. It is said that just before the war between Chili and Peru he satisfied himself that the Peruvians would be defeated and that they would lose the province of Tarapaca. Some of the *oficinas* he acquired by purchase, and when the conquering Chilians came to seize upon the lands they found the British flag flying over many square miles of nitrate beds, of which the owner was J. T. North. On his return to this country after an absence of nearly twenty years, Colonel North (he was honorary colonel of the Tower Hamlets Volunteer Engineers) soon became a familiar figure in the City, built himself a very fine house at Eltham, in Kent, started a racing-stable on a large scale, and became a prominent member of all the associations connected with sport. In 1889 he paid a visit to Chili to strengthen his companies by agreements with the Chilian Government. As a business man Colonel North's most remarkable achievement was his introduction of the Nitrate Railways Company and various nitrate of soda producing companies on the London market.

On the turf Colonel North's colours have frequently been carried to victory during the last seven years. In 1891 the amount he secured in stakes reached a total of £20,000. Colonel North took a keen interest in coursing as well as racing, and has bred several famous dogs, of which the most noted was Fullerton, the winner of the Waterloo Cup

for three years in succession. Encouraged by his success in various other fields, Colonel North at last determined to enter that of politics, and in 1895 contested West Leeds as a Conservative in opposition to Mr. Herbert Gladstone. After a remarkable contest, conducted by Colonel North upon novel electioneering principles, he was defeated by only 96 votes on a poll of over 12,000. The "Nitrate King" was nowhere more popular than in Leeds, which was his native place. In 1889 he presented to Leeds Kirkstall Abbey and its grounds, which he had purchased for £10,000, and he was a warm supporter of the numerous institutions both of the town and of the county. In recognition of his generosity he was in 1889 made an honorary freeman of the borough.

Colonel North was a member of the Institution of Mechanical Engineers, and in 1890 was elected a member of the Iron and Steel Institute. He took part in the Brussels meeting in 1895, and was much interested in the welfare of the Institute.

ADDITIONS TO THE LIBRARY

DURING THE FIRST HALF OF 1896.

Title.	By whom Presented.
"Iron and Steel Industries in 1894." Statistical Report of British Iron Trade Association. London. 1895.	British Iron Trade Association.
"I Tesori Sotterranei dell' Italia." By G. Jervis. 4 vols. Turin. 1873.	Purchased.
"Gleanings from Patent Laws of all Countries." By W. Lloyd Wise. London. 1895.	The Author.
"First Annual General Report upon the Mining Industry of the United Kingdom." By Professor H. le Neve Foster. London. 1895.	The Author.
"Real Index über die wichtigsten bergmännischen pyrotechnischen Werke und Artikel. By August Aigner. Vienna. 1895.	Purchased.
"Pig Iron Statistics." By E. W. Crawley. Leeds. 1896.	The Author.
"Manuel de la Métallurgie du Fer." By A. Ledebur. 2 vols. Paris. 1895.	F. Valton.
"The Colliery Manager's Handbook." By C. Pamely. London. 1893.	H. Bauerman.
"Presidential Address to the Geological Section of the British Association." By W. Whitaker. London. 1895.	The Author.
"Deep Borings at Culford." By W. Whitaker. London. 1894.	The Author.
"The Production of Natural Gas in 1894." By J. D. Weeks. Washington. 1895.	The Author.
"Proceedings of the Alabama Industrial and Scientific Society." Vol. v. 1895.	The Society.
"Aluminium." By A. G. Brown. Manchester. 1895.	The Author.
"Griffin's Electrical Engineers' Price Book." By J. Dowsing. London. 1896.	The Publishers.

Title.	By whom Presented.
"Salten og Ranen." By H. L. Vogt. Christiania. 1891.	John Crum.
"The Modern Office Building." By Barr Ferree. New York. 1896.	The Author.
"Directory to the Iron and Steel Works in the U.S." Philadelphia. 1896.	American Iron and Steel Association.
"Tabulated Weights of Iron and Steel." By C. H. Jordan. 5th edition. London. 1896.	The Author.
"The Making of the Dassett and Edge Hills of South Warwickshire." By Edwin A. Walford. London. 1895.	The Author.
"Excursion to Banbury, Bloxham, Edge Hill, and Hook Norton." By Edwin A. Walford. London. 1895.	The Author.
"Papers and Reports relating to Minerals and Mining." New Zealand. 1896.	The Minister of Mines for New Zealand.
"Annual Report of the Director of the Michigan Mining School." Michigan. 1895.	E. Wadsworth.
"Die Deckung des Erzbedarfs der deutscher Hochofen." By E. Schrödter. Düsseldorf. 1896.	The Author.
"A Sketch of the Early History of the English Patent System." By E. Wyndham Hulme. London. 1896.	The Author.
"Annual Report of the Harbour Commissioners of Montreal for year 1895. Montreal. 1896.	The Commissioners.
"Report of the Sheffield Smoke Abatement Association." By R. Heber Radford. Sheffield. 1896.	The Author.
"Alloys of Nickel and Iron." By Dr. J. Hopkinson. London. 1890.	The Author.
"Steel Works Analysis." By Professor J. O. Arnold. London. 1895.	The Author.
"Chromium and Tungsten and their Alloys." By Thomas Blair. Sheffield. 1890.	The Author.
"Official Year Book of the Scientific and Learned Societies." London. 1895.	Purchased.
"Bulletin of the Department of Labour." Washington. May 1896.	Carroll D. Wright.
"The Life of Sir William Siemens." By W. Pole. London. 1888.	Purchased.
"Arte Siderurgica." By V. Zoppeti. 2 vols. Milan. 1883.	Purchased.
"Die Huttenwesens-Maschinen." By J. von Hauer. Vienna. 1867.	Purchased.

Title.	By whom Presented.
"Traité pratique du Laminage du Fer." By F. Neveu and L. Henry. Paris. 1881.	Purchased.
"Die Stabeisen und Stahl-Bereiting in Frisch-berden." Freiberg. 1858.	Purchased.
"Bulletin de la Société de l'Industrie Minérale." 1855–1894.	Purchased.
"Ausfuhrliches Handbuch der Eisenhütten-kunde." By Dr. Hermann Wedding. Vol. i. Brunswick. 1891–1896.	The Author.
"Gemeinfassliche Darstellung des Eisenhütten-wesens." By T. Beckert and E. Schrödter. 3rd edition. Düsseldorf. 1896.	The Authors.
"Hüttenkunde." By T. Beckert and A. Brand. Stuttgart. 1895.	Purchased.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Imperial Institute.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

PROVINCIAL.

Cleveland Institution of Engineers.
Engineering Society (Leeds).
Hull and District Institution of Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Liverpool Polytechnic Society.
Manchester Association of Engineers.
Manchester Geological Society.
Mason Science College (Birmingham).
Merchant Venturer's School (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining Engineers.
Sheffield Technical School.
South Staffordshire Institute of Iron and Steel Works Managers.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
University College of South Wales.

COLONIAL AND FOREIGN.

Colonial.

Canadian Institute.
Canadian Society of Civil Engineers.
Department of Mines, Sydney.
Department of Mines, Melbourne.
Geological Survey of Canada.
Geological Survey of India.
Mining Society of Nova Scotia.

United States.

American Association for the Advancement of Science.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Bureau of Statistics.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

Austria.

K.k. geologisches Reichsanstalt.
Oesterr. Ingenieur und Architekten-Verein.

Belgium.

Ministère de l'Interieur.

France.

Comité des Forges.
Le Ministère des Travaux Publics.
"Revue Maritime."   Ministère de la Marine.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Ingenieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute.   (Journal " Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

Ministero di Agricoltura.
Reale Accademia dei Lincei.

Japan.

Department of Mines.

Sweden.

Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective
Editors :—

UNITED KINGDOM.

" Bimetallist."
" British Trade Journal "
" Coal and Iron."
" Commerce."
" Contract Journal."
" Colliery Guardian."
" Daily Tenders and Contracts."
" Electrician."
" Electrical Plant."
" Electrical Engineer."

"Engineer."
"Engineer and Iron Trades Advertiser."
"Engineering."
"Engineering Review and Metal Worker."
"Engineers' Gazette."
"Hardwareman."
"Hardware Trade Journal."
"Industries and Iron."
"Iron and Steel Trades Journal."
"Iron and Coal Trades Review."
"Ironmonger."
"Ironmongery."
"Iron Trades Circular."
"Marine Engineer."
"Money."
"Machinery Market."
"Phillips' Monthly Register."
"Plumber and Decorator."
"Practical Engineer."
"Railway Engineer."
"Railway World."
"Shipping World."
"Statist."
"Steamship."
"The London Technical Education Gazette."
"Transport."

COLONIAL AND FOREIGN.

Colonial.

"Canadian Mining Review."
"Indian and Eastern Engineer."
"Indian Engineering."

United States.

"Age of Steel."
"American Journal of Science."
"American Manufacturer."
"Bradstreet's."
"Cassier's Magazine."
"Colliery Engineer."
"Digest of Physical Tests."
"Engineering and Mining Journal."
"Engineering Magazine."
"Engineering News."
"Iron Age."
"Iron Trade Review."
"Railroad Gazette."
"Report of Proceedings of the Master Car Builders' Association."

Austria.

"Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

"Association des Ingénieurs de Liége."
"Association des Maîtres des Forges de Charleroi."
"Bulletin de l'Union des Charbonnages de Liége."
"Moniteur des Interêts Materiels."
"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Portefeuille Économique."

Germany.

"Annalen für Gewerbe und Bauwesen."
"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen und Stahl Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen
    Staate."
"Zeitschrift für praktische Geologie."

Italy.

"L'Industria."
"Rassegna Mineraria."

Spain.

"Revista Minera."

Sweden.

"Teknisk Tidskrift."

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

CONTENTS.

ABSTRACTORS.

EDWIN J. BALL, PH.D.

BENNETT H. BROUGH, ASSOC. R.S.M.

IRON ORES.

CONTENTS.

I.—OCCURRENCE AND COMPOSITION.

Austrian and Hungarian Iron Ores.—C. von John and C. F. Eichleiter * give the results of analyses of a number of iron ores from Austria and Hungary. The following are the results of the analyses of (1) brown iron ore from Paliban in Hungary, (2) iron ore from Szuchy, (3) from Mutterka, and (4) from Génir :—

	1.	2.	3.	4.
Silica	26·42	3·20	6·56	16·52
Ferric oxide	41·36	72·34	78·80	66·72
Manganous oxide	9·64	3·27	2·05	3·16
Alumina	10·58	0·26	0·16	5·30
Lime	0·92	5·60	0·80	3·92
Magnesia	0·10	0·81	0·12	2·45
Sulphur	0·002	0·04	0·06	0·04
Copper	...	0·035	0·067	0·007
Phosphorus	0·23	...	...	...
Loss on ignition	10·14	15·18	12·80	4·18

E. Döll † describes some new occurrences of minerals in Upper Styria. From the Flitzen he obtained specular iron ore. The serpentine of

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* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlv. pp. 13–15.
† *Verhandlungen der k.k. geologischen Reichsanstalt*, 1895, pp. 457–461.

the Lerchkogel at Trieben often contains very small octahedra of magnetite.

He also describes* a new pseudomorph of limonite after breunnerite from the magnesite of Vorwald in Styria, and pseudomorphs of magnetite after micaceous iron ore and of pyrolusite after calcite.

Magnetite in Minette Ore.—L. Hoffmann† notes that in the Moyeuvre mine at Gross-Moyeuvre, in the minette region of Lorraine, an ore occurs above the grey bed, which differs in appearance very considerably from ordinary minette. The oolitic structure has almost entirely disappeared, and is replaced by a finely granular one. The colour of the ore is steel-grey to iron-black, with a distinct metallic lustre. The ore has a powerful action on the magnetic needle, and may consequently be regarded as magnetite. It forms a bed $3\frac{1}{2}$ to 7 inches thick, and extends for several hundred square yards. It crops out at the surface in the valley of the Conroy stream. As dislocations are met with only at a considerable distance from the locality, it may safely be assumed that the conversion of the ferric hydrate into magnetite was the results not of tectonic but of purely chemical influences.

The Iron Ore Deposits of the Harz Mountains.—The deposits of iron ore which are met with in the northern foot-hills of the Harz mountains have been known from ancient times, and although these deposits are at a considerable distance from the coalfield of Westphalia, yet at many points they have given rise to important industrial progress.‡ Geologically the ore deposits occur in various horizons of the Jura and the Chalk. In the Lias the iron ores occur mostly in the form of accretions and boulders, but in places, as at the Friederike mine, near Harzburg, in large oolitic deposits. In the Chalk, large deposits of very variable composition are met with. Large conglomerate masses are found which are extremely variable in size and in petrographic character. Portions of older and newer rocks are mingled together in these conglomerate beds, and the occurrence of fragments of Amm. spinatus is apt to lead to inaccurate decisions in judging the age of the beds.

Analyses of Iron Ores.—E. Schrödter§ publishes, amongst others, the following analyses of iron ores :—

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* *Verhandlungen der k.k. geologischen Reichsanstalt*, 1895, pp. 456–457.

† *Zeitschrift für praktische Geologie*, 1896, pp. 68–69.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 532.

§ *Stahl und Eisen*, vol. xvi. pp. 265–268.

	Fe.	Mn.	S.	P₂O₅.	SiO₂.	Al₂O₃.	CaO.	MgO.	Residue or Loss.
German Ores:—									
Clay ironstone	36·70	0·60	0·50	0·36 (P)	...	...	...	...	15·3
Magnetite	58·20	...	0·55	0·01	7·85	3·00	2·66	1·13	...
Brown hæmatite	53·40	0·70	trace	2·24	6·08	4·58	0·82	...	...
Sphærosiderite	54·50	1·56	trace	3·78	8·67	1·84	5·55	1·01	...
Spathic ore	38·40	3·21	0·25	0·02 (P)	3·15	0·12	3·49	1·34	...
Red hæmatite	35·10	0·21	...	0·48 (P)	12·14	9·11	8·93	...	...
Oolitic ore	38·01	0·49	...	1·16 (P)	23·09	7·63	2·69	...	...
Pisolitic ore	23·33	...	...	...	...	26·15	14·60	1·07	15·49
Minette	38·09	0·16	0·23	0·43 (P)	15·09	5·71	10·37	2·10	11·34
Blackband	47·69	1·12	1·29	1·57 (P)	9·75	3·26	6·39	2·84	1·60
Blackband	21·21	0·57	1·06	0·58	4·98	1·64	2·87	1·27	58·56
Siegen spathic ore, calcined	47·4-51	9·3-10	...	...	7·7-13	...	...	...	...

He also gives the following analyses of ores derived from other countries, and of slags, &c :—

	Fe.	Mn.	S.	P.	SiO₂.	Al₂O₃.	CaO.	MgO.	Residue or Loss.
Bilbao red hæmatite	54·50	1·02	...	0·028	...	1·23	1·8	0·25	10·8
Manganiferous ore, Carthagena	26·25	19·96	...	0·034	8·15	...	...	...	...
Seriphos ore, Greece	51	1·2	0·16	0·050	...	...	...	...	9
Manganese ore, Poti	1	52	...	0·17	8	4	...	...	...
Tafna ore, Algiers	58	1·8	...	0·03	...	...	...	...	5·1
Mokta ore, Algiers	58·5	1·7	0·44	0·01	4·8	2·0	1·5	0·7	...
Slags, &c. :—									
Open-hearth	14	10	...	0·3-0·9	...	...	...	30	24
Tap cinder	56	0·8	...	4	...	13	...	...	...
Reheating furnace	50	0·25	...	0·3	...	30	...	...	...
Blue Billy	65·5	...	1·71	...	...	2·37	...	...	...
Purple ore	64·9	0·02	0·47	0·1	2·77	0·26	0·41	0·07	...

These are only a few of a very large number of analyses, the samples to which they referred being shown in connection with the author's paper on the ore requirements of the German blast-furnaces. Altogether he gives analyses of over one hundred different samples of German and Luxemburg iron ores, and of nearly thirty other iron ores and slags.

The Elbingerode Iron Ore Deposits.—In North-Western Germany iron ores are found widely distributed in beds of sedimentary age. They are found in quantity in Devonian, Jurassic, Chalk, and Post-Pliocene beds. The Devonian ore deposits are confined to the district of the Harz. The ore deposits formerly worked were directly connected with the limestone beds, the Iberger deposits being a case in point.

From time immemorial, however, the Elbingerode basin was the most important of these ore deposits, and this is the only one still at work.[*] They have been found for a length of some two miles, and in a variable thickness, rising in places to about 33 yards. In addition to the main deposit minor ones are also in existence. Formerly, as now, open-workings have been mainly employed in the winning of the ores. These are of variable composition, the percentage of iron ranging as a rule between 20 and 50. They include brown hæmatite, calcareous red hæmatite, pure hæmatite, magnetite, and in places an argillaceous spathic carbonate. To the west of Elbingerode there was found associated with these iron ores a rich deposit of manganese ore. Pyrites was also found. This manganese bed has, however, now been worked out. The ores were formerly worked at a considerable number of adjacent works. Now, with only four mines at work, the active ironworks are confined to the charcoal furnaces at Rothehütte near Elbingerode, and at Zorge, in the Southern Harz.

The Iron Ore Deposits of Osnabrück.—Near Osnabrück [†] is a range of hills consisting of sandstones and conglomerates of New Red Sandstone age. To the north lie beds of a black clay slate, corresponding to the Mansfeld copper slate, and then limestones of the Permian age. Towards the outcrop these have been transformed into ochre, and in this in places beds of solid brown hæmatite are found. This ochre is manganiferous, and varies from about 5 to 38 yards in thickness. Its transition into dolomitic ferruginous limestone is gradual. This latter contains successive beds of spathic iron ore corresponding to those of brown hæmatite found in the ochre. The ores have been mined for a number of years, but the mining is now less extensive. In the year 1894–95 the quantity of ore raised amounted to 118,326 tons.

Similar ores are found at the Schafberg, near Ibbenbüren. Here, as at the deposits above referred to, open-workings are used almost exclusively, but deep mining is partially employed. At the Hector mine the massive brown hæmatites pass in the deep into spathic iron ore or become fissure fillings in the Permian limestone. The presence of carboniferous beds on the foot-wall is discernible. At the Perm mine there is a mass of ochre from 13 to about 24 yards in thickness, which includes occasional inclusions of brown hæmatite. Three mines produce between them about 50,000 tons of ore a year.

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 588.
[†] *Ibid.*, p. 589.

Bog Iron Ore in Hanover.—In the Bentheim district of Hanover bog iron ores are won. These average about 45 per cent. of iron, and contain 0·5 to 1·5 per cent. of phosphorus, together with some 13 per cent. of insoluble residue. They are found about a foot below the surface, and vary up to some 2 feet in thickness. They are subjected to further preparation after being mined. Since 1880 one company employing forty men has raised over 200,000 tons of ore.*

Iron Ore of the North of Norway.—Under the auspices of the Geological Survey of Norway, J. H. L. Vogt † has published a volume of 232 pages, with six folding plates and nine illustrations in the text, giving a geological description of the district of Nordland, with special reference to the mineral deposits. The Tromsö mica-schist marble group of rocks is characterised, at Näverhaugen in Salten, at Dunderlandsthal and Fuglestrand in Ranen, and at other places, by the occurrence of very thick and extensive deposits of iron ore in intimate connection with the limestone. At Näverhaugen the ore bed, consisting of specular iron ore, quartz, &c., may be followed for over five miles with a thickness varying from 1 foot up to 15 yards. The area of iron mica-schist or itabirite in Ranen extends for 24 miles. In Dunderlandsthal, two thick beds of limestone occur with iron mica-schist on the lower side. In places the iron ore penetrates the limestone. The thickness of the ore at Dunderland varies from 10 to 65 yards, and at Kvitinge it is not less than 95 to 100 yards. Mineralogically and petrographically, the two iron ore deposits at Näverhaugen and in Ranen are very similar. Specular iron ore predominates in both cases, and there is but little magnetite. Other minerals present are quartz, hornblende, magnesium, mica, garnet, epidote, felspar, a very little calcite, and titanite. There is a fairly high proportion of apatite (average 0·15 to 0·2 per cent. of phosphorus), and very little sulphur and titanium.‡

The Iron Ore of Nissedal.—J. H. L. Vogt § describes the occurrence of iron ore rich in apatite in the Nissedal, Thelemarken, Norway. Owing to want of means of transport, the ore has not hitherto been worked. The deposit consists of three beds respectively, 45, 190, and

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 590.

† *Salten og Ranen.* A copy of the original has been presented to the library of the Institute by Mr. John Crum.

‡ Compare *Journal of the Iron and Steel Institute*, 1894, No. II. p. 278.

§ *Norges Geologiske Undersögelse.* No. 17 ; *Zeitschrift für praktische Geologie*, 1896, pp. 78-79.

210 yards in length and 2 to 6 yards in thickness, intercalated in gneiss, hornblende schist, and mica-schist. The ore consists of magnetite and specular iron ore, accompanied by apatite, quartz, felspar, and hornblende. The proportion of apatite amounts to 20 per cent. (3·5 per cent. of phosphorus). On an average, ore can be mined with 50 to 60 per cent. of iron and 1·75 to 2·0 per cent. of phosphorus.

The occurrence belongs to the great group of iron ore beds in crystalline schists, as represented at Grängesberg, Dunderland, Norberg, Persberg, and Dannemora.

Iron Ore in Portugal.—R. Fisher [*] states that iron ore is distributed generally over northern Portugal. A valuable deposit of magnetic iron ore at Moncorvo, about 80 miles up the river Douro, is not worked on account of difficulties of transport. In the Pombal district, 30 miles north from Leira, there are numerous traces of Moorish smelters. Some of the ore is similar to the rubio, but contains more phosphorus. Manganese ore has been worked to a small extent.

Iron Ore from Servia.—S. M. Losanitsch [†] gives the following results of an analysis of magnetite from Vencac :—

Insol.	Fe₂O₃.	FeO.	Cr₂O₃.	Al₂O₃.	MgO.	Loss on Ignition.	Total.
11·68	60·34	7·92	4·49	4·44	5·44	5·46	99·77

A. Stanojevic [‡] gives the following results of an analysis of magnetite, specific gravity 5·01, from Suvo Rudisté :—

Insol.	CuO.	MgO.	Fe₂O₃.	FeO.	CO₂.	Total.
1·59	4·03	0·80	67·37	27·63	0·11	101·53

Iron Ore in the South of Spain.—In the paper by A. P. Wilson [§] on "The Iron Ores of the Mediterranean Seaboard," mention was made of the Lucainena mines in Sierra Alhamilla, south of Spain. The shipping pier at Agua Amarga and railway to the mines are now practically completed. From the purity and richness of this ore it is being freely sold in England. Analysis of various samples sent to England confirms

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* *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 124–125.

† *Annales géologiques de la Péninsula Balkan*, vol. iv. pp. 81–86.

‡ *Ibid.*, pp. 86–88.

§ *Journal of the Iron and Steel Institute*, 1894, No. II. p. 182.

the results given in Mr. Wilson's paper. An average analysis [*] of Lucainena ore taken from three samples gave the following results:—

Ferric oxide	76·510
Ferrous oxide	none
Peroxide of manganese	5·144
Alumina	0·882
Lime	2·185
Magnesia	1·336
Silica	5·798
Sulphate of barium	0·035
Baryta	none
Phosphoric acid	0·015
Arsenic	trace
Copper oxide	0·002
Lead oxide	trace
Oxide of nickel and cobalt	none
Zinc oxide	trace
Carbonic acid	2·950
Combined water	4·450
Bi-sulphate of iron	none
Titanic acid	0·014
Sulphuric acid	0·125
Moisture	1·430
	100·876
Iron	53·57
Manganese	3·68
Phosphorus	0·007
Sulphur	0·049

The Iron Ore Deposits at Delémont.—At Delémont, in the Swiss Jura, is a deposit of pisolitic brown iron ore. This is described by M. von Isser,[†] who states that at one time there were numerous small iron ore workings, all now abandoned, in the Canton Valais, and that now there are in operation there only a few small anthracite mines with an output of some 4000 tons a year. Four other brown coal, &c., pits are in operation in the Cantons of Zurich and St. Gallen, with a total output of about 3000 tons, and about 7000 tons of asphalt is raised yearly in the Canton of Neuchatel. In addition to these there are in Switzerland useful deposits of pisolitic iron ore at Delémont, in the Jura. The author mentions the geological formations existing in this neighbourhood, and states that the iron ore is found at the junction of the Tertiary deposits with the Jurassic Portland beds. He

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[*] Communicated by Mr. J. W. Spencer, 27th January 1896.
[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliv. pp. 200-204, four illustrations.

gives four analyses of the washed ore from different workings. These vary from—

	Per Cent.
Ferric oxide	62·750–65·250
Titanium	2·050– 2·500
Chromium	1·250– 1·750
Alumina	9·875–10·750
Vanadium	0·350– 1·000
Silica, &c.	5·500– 7·500
Moisture	13·500–16·105

The ore is smelted at two blast-furnaces at the Helvetia Works at Rondez, hot blast being employed, but with charcoal as the fuel, together with French coke. The yield varies from 50 to 52 per cent. One blast-furnace is used for direct castings, the other making pig iron. Of the former 1750 tons were made in 1895, and of the latter 6450 tons. The other furnaces and appliances in use at the works are also mentioned.

Iron Ore in Ontario.—W. H. Merritt [*] gives a sketch of the economic minerals of the province of Ontario, Canada, and in this devotes some space to the iron ores which occur to a considerable extent. In the eastern part, the ores occur in the so-called Upper Laurentian formation in crystalline limestones, or at their junctions with other rocks, such as greenstones and hornblendic gneiss; or, again, the ores are found in greenstones. Most of the deposits have been discovered not far to the north of the Silurian fringe. Into the western part of the province the great Vermilion and Mesabi ranges extend, and give promise of considerable extent, but have not yet been much prospected or worked. In the northern part R. Bell reports an important bed of spathic ore partly altered to limonite in the Carboniferous formation.

Iron Ore in Newfoundland.—R. E. Chambers [†] describes the iron ore deposits on Bell Island, in Conception Bay, Newfoundland. This island is 8 miles long by 2 miles in width, and is 35 miles from St. Johns. On the north side are exposed five beds, of which three are thin and two are workable. The lower bed outcrops for $3\frac{1}{2}$ miles, and exposes a thickness of 7 to 10 feet in places adapted for open-cast workings. The upper bed shows in parts a thickness of 6 feet of ore, with 57 per cent. of iron. Analyses of the lower bed show :—

Iron.	Silica.	Alumina.	Phosphorus.	Sulphur.	Calcium Carbonate.	Oxide of Manganese.
54 to 59	5 to 12	2 to 4	0·5 to 0·7	trace to 0·012	3 to 5	trace to 0·4

* *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 301–304, with map.

† Paper read before the Mining Society of Nova Scotia, through the *Iron Age,* vol. lvii. pp. 808–810.

A map and sections of the district are appended. The ropeways and tramways used for leading the ore to the shipping pier are also described.

Iron Resources of Minnesota.—H. V. Winchell * gives comparative statistics of the production of iron ore and iron in various countries of the world, and of the several States in the United States. As far as iron ore is concerned, Alabama and Minnesota have only taken prominence recently, but Minnesota was second in the production in 1894, and will probably surpass even Michigan in 1896. The shipments from St. Louis county alone are close on four million tons in 1895, and since 1884, when the mines were opened, they amount to about 13½ million tons. Duluth is the centre of this county, which contains the Vermilion and Mesabi ranges. Development on the former is practically confined to two points, Tower and Ely. The value of the iron ore is then discussed with regard to its quality, accessibility, and quantity, and under these headings is compared with that from other localities.

According to F. B. Richards † some 97 million tons of ore were shipped from the Lake Superior district between the close of navigation in 1895 and 1855, when the industry commenced. Since 1889 rather more than half this total has been carried. Before 1855 only a small amount of ore was produced for local consumption in bloomeries. When shipping commenced the ore was hauled in waggons, and loaded by hand into boats of 150 to 300 tons capacity. Now every port has enormous docks, some of them carrying 50,000 to 60,000 tons of ore in pockets, and by means of shoots no less than 2400 to 2500 tons of Mesabi ore were loaded into a vessel's hold in seventy minutes at Duluth. Where the ore is coarser the average time is three to five hours. The author then gives a brief review of the several ore ranges in the district, and the ports.

The Mesabi Iron Ore Mines.—H. Wedding ‡ describes the Mesabi mines. It is customary in Europe, the author observes, to assume that all the red hæmatite which is mined in the Lake Superior districts is sufficiently free from phosphorus to admit of its use for the acid Bessemer process. This view, he points out, is erroneous. It was long the custom in the United States to consider those ores to be suitable for

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* Paper read before the North-Western Immigration Convention at St. Pauls, 21st November 1895, through the *Iron Trade Review*, vol. xxviii. No. 49, pp. 11–13.

† *Iron Age*, vol. lvii. pp. 43–44.

‡ *Stahl und Eisen*, vol. xvi. pp. 7–13, with five illustrations taken from the *Iron Age* and one from *Harper's Weekly*.

the acid Bessemer process which, for every 1 per cent. of iron they contained, contained not more than 0·001 per cent. of phosphorus. That is to say 0·06 per cent. of phosphorus for an ore containing 60 per cent. of iron. Pig iron with more than 0·1 per cent. of phosphorus was considered unsuitable in the acid process. This limit has, however, been gradually lessened, and now the maximum is placed at 0·085 per cent. A 60 per cent. ore to be of Bessemer grade must therefore contain not more than 0·051 per cent. of phosphorus, and even 0·045 is often stipulated for, especially in the case of Mesabi ores, which are of a very earthy character. In consequence of this, only one-third or one-fourth of the blast-furnace charge can consist of these ores. The hard lump ore of the Marquette range is often classed as Bessemer ore, even when containing 0·08 per cent. of phosphorus. The author describes the range, the illustrations showing both the character of the country and the methods of mining which are in use. He gives statistics relating to the output of ore, and the following complete analysis of ore from the Biwabik mine :—

	Per Cent.
Iron	65·200
Silica	2·790
Phosphorus	0·027
Manganese	0·313
Alumina	0·647
Lime	0·340
Magnesia	0·123
Sulphur	0·003
Organic and volatile matter	2·650

The ore in the Mesabi range is apt to vary in character with the depth, as the following assays of ore from the same shaft show :—

Depth. Yards.	Percentage of Iron.	Percentage of Phosphorus.
3	52·00	0·135
3 to 6	58·55	0·153
6 to 9	56·30	0·171
9 to 12	40·55	0·145

As showing the use made of water transport, the author states that in 1894 there passed through the St. Mary Falls Canal 14,491 vessels in 234 days, laden with 13,195,860 tons of freight, of which 6½ million tons was iron ore and 2½ million tons coal. In the same year the Mountain Iron Mine produced 319,000 tons of ore, averaging 64·18 per cent. of iron and 0·043 of phosphorus, and the Oliver Mine 172,350 tons of ore, containing 63·50 per cent. of iron, 0·059 of phosphorus, and 9·37 of moisture. Statistics relating to a number of the larger mines are given, the ore varying in percentage composition as follows :—

Iron.	Phosphorus.	Moisture.
59·60 to 64·61	0·033 to 0·082	3·12 to 9·37

Iron Ore in Iowa.—In the Annual Report of the Iowa Geological Survey,* S. Calvin states that in Allamahee county the amount of iron is, in general, too small to have any commercial significance. There are, however, two or three points within the Trenton area at which ore, partly true hæmatite and partly the hydrated form called limonite, occurs in considerable amount, and may some time be worked at a profit. The ore beds are on the highest points near Waukon. Some of the concretions disintegrate more or less. The beds are all underlain by from 50 feet to 100 feet of Trenton limestone, with the exception that on the south side of Iron Hill the ore comes down so as to partly overlap the Saint Peter limestone. The ore is a comparatively thin layer lying over the hill-top.

Brown Iron Ore in Virginia.—E. C. Pechin † describes the extensive development of the Oriskany iron ores at the Rich Patch mines in Alleghany county, Virginia. Iron made from similar ore from adjacent properties has long been known as of good quality. The property in question covers some 9000 acres, and runs for seven or eight miles in a south-west direction, and throughout ore indications are observed. In many places the ore body averages 25 to 30 feet in thickness over considerable distances, and it would appear that there are two distinct seams, though it has often been assumed that there was only one. At numerous points adits can be driven in order to drain 300 to 400 vertical feet of ore, so that the cost of mining will be low. A description is given of the various exploratory works that have been done, and of the six openings from which ore is being extracted. There is sufficient water on the property to wash 300 to 400 tons daily, and a further supply is being sought. A revolving barrel washer and a picking belt is used for treating the ore. Average analyses show 46 to 50 per cent. of iron. The Clinton No. V. ores are also worked here, and average 3 feet in thickness. The question of the utilisation of these ores and of erecting local furnaces is also discussed.

E. J. Schmitz ‡ gives a description of a section through the Rich Patch Mountain at Iron Gate, Virginia, obtained during an examination of the iron ore resources of the neighbourhood. Full notes and measurements are given. The geological members below the Oriskany and Lower Helderberg are exposed along the gap in a beautiful arch, while

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* *Third Annual Report*, vol. iv.
† *Engineering and Mining Journal*, vol. lxi. pp. 113, 134, 159.
‡ *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting).

the higher formations appear in a more or less disturbed state on both sides of this arch, and are partly covered by débris.

Iron Ore at Hartville, Wyoming.—E. P. Snow * describes the iron ore deposits at Hartville, Wyoming, a hundred miles north of Cheyenne. The ore belt is on the north bank of the river Platte, in Laramie county. It is two or three miles wide, and covers about 25 to 30 square miles. The ore is found in slate or ʰetween limestone and slate, apparently existing as lenses of unknown depth. In one mine a shaft 150 feet in depth has not penetrated the ore body, which is exposed for a length of 1100 feet and a breadth of 200 to 300 feet. Other deposits appear to be equally large. The ore averages about 60 per cent. of iron ; two analyses show besides traces of lime and magnesia :—

Iron.	Alumina.	Silica.	Sulphur.	Phosphorus.
67·55	1·42	1·50	0·054	0·008
68·41	1·86	1·82	0·019	0·035

They are thus Bessemer ores. The ore is a red hæmatite, both hard and soft. Good limestone flux is found in connection with the ore, and timber is plentiful within a short distance. A sketch map of the district is given.

Algerian Iron Ores.—The deposits of iron ore at Mouzaia, in Algeria, have hitherto been of no commercial value owing to the absence of adequate transport facilities. These deposits are among the most important in the Mediterranean.† The ores found are red and brown hæmatites, derived from spathic carbonate. The deposits have as yet been but little examined, but some of them are known to extend for a distance of several miles in length, and to have a thickness of from 15 to 20 yards and more. There are six principal veins, and analyses have shown them to contain from 58 to 62 per cent. of iron, 0·82 to 1·38 of manganese, and about 0·011 of phosphorus. One analysis showed 0·29 per cent. of sulphur. The estimated cost of the metric ton of ore, f.o.b. at Algiers, is placed at 8·51 francs (about 6s. 9d. per ton).

M. Tingry ‡ has published the following results of an analysis of iron ore from Oued-Tiffa, Algeria :—

Insoluble residue.	SiO₂.	Al₂O₃.	Fe₂O₃.
3·79	17·32	0·39	78·88

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* *Engineering and Mining Journal*, vol. lx. pp. 320–321.

† *Echo des Mines*, vol. xxi. pp. 61–64, 90-94, 124–127.

‡ *Annales des Mines*, vol. yiii. p. 184.

M. Sergère, * on analysing a sample of brown hæmatite from Bona, found 49·28 per cent. of iron. In red hæmatite from the same locality he found 52·63 per cent. of iron.

A Ferruginised Tree.—O. C. S. Carter † describes a ferruginised tree found in Montgomery county, Pennsylvania, in a quarry of loose disintegrated sandstone. It was lying about 10 feet below the surface, just above the solid rock, and consisted of a log about 15 feet in length and 6 to 10 inches in diameter. In its greater part the wood was replaced by brown hæmatite, but the woody structure, converted into lignite, was retained in parts.

Magnetic Pyrites.—A. Abt ‡ observes that pyrrhotite can be made distinctly magnetic, more so, indeed, than magnetite. The increase in the magnetism, as in the case of iron, steel, nickel, and magnetite, takes place at first more strongly, and subsequently more slowly than the increase in the current, but magnetite attains its maximum sooner.

Artificial Martite.—Martite is now generally considered to be hæmatite pseudomorphous after magnetite. On heating crystals of magnetite, weighing 0·4499 gramme, before the blowpipe for five hours, C. Friedel § finds that there is a gain in weight corresponding with the change from Fe_3O_4 to Fe_2O_3. The crystals lose their magnetic properties, but are only slightly changed in outward aspect. The mineral has thus been changed from magnetite to hæmatite.

Recent Researches on Meteorites.—O. C. Farrington ‖ has prepared a handbook and catalogue of the meteorite collection in the Field Columbian Museum of Chicago. The remarkable collection of meteorites that the museum has already acquired includes 180 falls or finds aggregating 4721 lbs. in weight. Conspicuous among the rest are two specimens from Kiowa county, Kansas, weighing 466 and 345 lbs., specimens from Phillip's county, Kansas, aggregating 1184½ lbs., and two masses from Cañon Diablo, Arizona, weighing 1013 and 256 lbs.

E. Goldsmith ¶ describes a hardened steel meteorite, weighing 267 lbs.,

* *Annales des Mines*, vol. viii. p. 188.
† *Journal of the Franklin Institute*, vol. cxli. pp. 227–229.
‡ *Glückauf*, vol. xxxii. p. 109.
§ *Bulletin de la Société Française de Minéralogie*, vol. xvii. pp. 150–151.
‖ *Geological Publications of the Field Columbian Museum*, vol. i. No. I., 65 pp. with plates. Chicago, 1895.
¶ *Journal of the Chemical Society*, vol. lxx. p. 41.

brought from near Godhaven, Disko Island, Greenland, by the Peary
Expedition of 1891; when received it appeared quite fresh, but it soon
became cracked and fell to pieces. These pieces were easily separated
into hard metallic granules (73·8 per cent. of the whole) and a magnetic
powder. The granules were extremely hard and difficult to cut (no
diamond was found), but on being heated and slowly cooled they became
soft. Their composition is given as :—

Fe.	Ni.	Troilite.	Magnetite.	Silicate.	Sp. gr.
66·79	2·32	0·52	25·96	4·41	6·14

Traces of carbon, phosphorus, and chromium were found, but neither
copper nor cobalt, which are found in the Disko terrestrial iron, together
with more carbon than here. The composition of the powder is given
as :—

Fe.	NiO.	Fe_2O_3.	$Fe_3O_4, 2SO_3$.	Silicate.	H_2O.	Sp. gr.
25·58	0·31	56·90	4·28	10·10	3·43	4·73

The "$Fe_3O_42SO_3$" is called "magnetic sulphate," as the whole of the
powder is stated to be magnetic.

J. C. H. Mingaye [*] describes a meteorite from Moonbi, Tamworth,
New South Wales. The meteorite, weighing 29 lbs., gave on analysis :—

Fe.	Ni.	Co.	Cu.	Sn.	Cr.	C (graphite).	C (combined).
91·350	7·886	0·564	trace	0·003	trace	0·068	trace

	SiO_2.	S.	P.	O.	Total.	Sp. gr.
	0·039	nil.	0·217	trace	100·127	7·833

According to E. E. Howell,[†] the Cherokee meteorite was found in
1894 near Cherokee Mills, Cherokee county, Georgia; weight 15½ lbs.
Widmanstätten figures are strongly marked; analysis I. The Losttown
meteorite, found in 1868 in the same county, is of different appearance
and composition, having only 3·36 per cent. of nickel.

	Fe.	Ni.	Co.	Cu.	P.	S.	Total.
I. . . .	91·96	6·70	0·50	0·03	0·11	0·01	99·31
II. . . .	90·51	8·40	0·60	0·05	0·24	trace	99·80

The El Capitan meteorite was found in 1893 on the northern slope of
the El Capitan range, New Mexico; weight about 61 lbs.; analysis II.
It is suggested that this may be the "fiery ball" seen in the neigh-
bourhood in 1882.

* Journal of the Chemical Society, vol. lxx. p. 193.
† American Journal of Science, vol. l. pp. 252–254.

Manganese Ore in the Caucasus.—In the year 1894 the exports of Caucasian manganese ore from the ports of Poti and Batoum amounted to 157,275 statute tons, as compared with 132,930 tons in the previous year. Of the total quantity exported from these two ports in 1894 only 9135 tons was shipped at Batoum; 65,110 tons of the ore went to the United Kingdom, 51,455 to Germany, 9890 to the United States, 28,300 to Belgium, and 2520 to France.*

The Manganese Ores of Sweden.—Three kinds of manganese ore are found in Sweden †—pyrolusite, hausmannite and braunite, and manganiferous iron ore. Pyrolusite occurs near Bölet in Vestergötland, in Småland, Dalarne, and elsewhere. The mode of occurrence of the ore at various places named is described. The best ores (in gneiss) from the Bölet mines contain from 53 to 61 per cent. of manganese. In 1894, 1636 tons of ore was mined. Ores from the Småland district are divided into three classes, the best of which contains 48·20 per cent. of manganese. In 1893, 3631 tons was obtained from specified mines in the district, but 2592 tons of this was from old waste heaps. In 1894 only 516 tons was obtained.

The second type of ore, hausmannite and braunite, occurs in Vermland and in the Sjö mine at Nerike. The ore consists mainly of hausmannite and braunite, but manganosite and pyrochroit in limestone, rhodonite, shefferite, and similar minerals also occur. The ore is found in either dolomite or limestone. In 1894 the Långban mines raised 1169 tons. This is at present the only active manganese mine in this field. The ore is used in steel making and in glass manufacture.

The third type of manganese ore consists of manganiferous ironstone. These are mainly magnetites, and in part bloodstone or jacobsite. The manganese minerals occurring in these are the silicates, such as knebelite, manganese garnet, rhodonite, and other manganese pyroxenes, dannemorite and other manganese amphiboles, the carbonate and silicate, jacobsite, and the oxides, the latter occurring in ores with high percentages of manganese, such as the Gladkärn ores. The ores are found in Archæan limestone and also in hälleflint. They are frequently strongly siliceous, and usually very calcareous. The ores are found in the Dannemora and Ramhäll fields in Upland, and at numerous other places in Gestrikland, Dalarne, Nerike, Vestmanland, Vermland, and in Dalsland. Usually the percentage of manganese does not exceed 6, but

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* *Deutsches Handelsarchiv,* 1895, p. 457.
† *Teknisk Tidskrift,* vol. xxvi. pp. 12–14.

occasionally the percentage is higher. Thus in the Röberg district near Norberg ores are found containing 26 per cent. of manganese, at the Gladkärn mine with 20 per cent., in the Svartberg district with 15 per cent., in the Penning mine and in the Hilläng district with 10 per cent., and in the Långvik field with 8 per cent. The following table shows statistics relating to the output of these ores in recent years :—

Ore Fields.	Percentage of Manganese.	Percentage of Iron.	Output, Metric Tons.		
			1890.	1893.	1894.
Dannemora	1·38	49·80	63,854	58,623	51,631
Burängsberg	2·59	{ 53·00 28·48 }	8,164	8,689	8,104
Viker	3·31	41·70	3,428	1,767	1,980
Klackberg and Kolning . .	4·40	{ 48·40 31·04 }	53,179	68,809	61,048
Langvik	6·72	35·68	6,738	8,483	6,740
Hilling	9·95	35·44	2,198	1,666	1,976
Svartberg	14·02	44·51	2,640	2,063	1,692

The percentages of manganese and iron given above are average analyses results by R. Åkerman and A. Tamm. Spiegeleisen is made at Schisshytta from the manganese carbonate and knebelite (ingelströmite) ores of the Svartberg and Hilläng fields. As a general rule, however, the ores are mainly used in the manufacture of pig iron for steel-making purposes.

Manganese Ore in East Tennessee.—According to W. M'Govern,[*] manganese ore occurs in considerable quantities in Shady Valley, in the eastern part of Johnson county, Tennessee. About 800 tons were taken from the Heberlin mine, which shows more ore *in situ*. Nearer the head of the valley some ore has been extracted, and it exists in massive form. Transport of the ore is somewhat difficult. Analyses of several occurrences are given as follows :—

	Silica.	Iron.	Manganese.	Phosphorus.
Heberlin, stock ore . .	1·62	4·60	51·05	0·075
Heberlin, washed ore . .	1·10	3·00	55·00	0·099
Coles	1·40	2·30	53·08	0·177
Wright Bank . . .	7·60	7·10	41·44	0·066
Sheafer Bank . . .	4·12	5·20	50·25	0·160
King Bank	1·70	16·10	40·87	0·052

[*] *American Manufacturer*, vol. lviii. p. 551.

II.—*IRON ORE MINING.*

Iron Ore Mining in Lake Superior Region.—J. P. Channing *
describes and compares two of the systems used in the Lake Superior
districts for mining iron ore. The first is known as the top-slice system
of caving, and is in use at the Lake Angeline mine. The second is the
sub-drift system of caving, and is at work at the Chandler mine in the
Vermilion range. At the first-named mine the ore body is spoon-shaped,
800 feet long and 300 feet in width. A shaft is sunk and a level driven
out to leave 75 feet of ore above it under the cover of sand. Rises
are put up to the sand every 100 feet, and from the top drifts of 50
feet long are put out each way. From these the ore is taken out in slices,
commencing with the top, and letting in the sand as the work proceeds.
In the second mine the ore lies in a trough 70 feet wide. Shafts are
driven on either side, and drifts are put out every 50 feet. Working
from below, upwards, by means of rises, a series of sub-drifts are put
out so as to divide the ore into a series of 12½ foot slices. This is mostly
done in the winter when shipping is suspended, and the main mass of
the ore is removed in the summer by working the slices in descending
order. The latter system has numerous advantages as the ore is more
thoroughly explored, nearly all the timber can be lowered into the work-
ing places, ventilation and safety of the men are both increased. A
detailed statement has recently been published † to show the separate
yearly production, since 1879, of all the iron ore mines in the five
ranges of the Lake Superior District.

Steam Shovel.—Illustrations have recently been published ‡ of the
60-ton Bucyrus steam shovel, which has been used for getting iron ore
on the Mesabi range. Its total weight is 125,000 lbs., and it is driven
by two steam cylinders 10 by 14 inches. In one mine it was used to
load 254,250 tons of ore in twenty-five days of ten working hours,
without blasting.

Iron Ore Mining at Lake Angeline.—To permit the mining of
iron ore at Lake Angeline about 800,000,000 gallons of water were

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* *The Mineral Industry*, vol. iii. pp. 375–402.
† *Iron Trade Review*, vol. xxix., No. 3, supplement.
‡ *Ibid.*, No. 6, pp. 8–9.

pumped out. A heavy deposit of mud remains, and is of a cream-like consistency, in some places 40 feet deep, but it could not be pumped away. The ore in many places comes up to the surface sand. To reach the ore, a shaft has been sunk in the diorite foot-wall on the north side of the lake. It is 5 by 18 feet inside, and is divided into four compartments. It has been sunk to the third level. At the first level, 150 feet below the original water level, only exploratory work has been done, but lower down about 76 rooms have been opened and the ore body has been followed for a distance of 2760 feet, and it has a thickness of 150 feet in parts. Some of the ore is below the Bessemer limit, but most of it is somewhat above that point.*

Rock Drills.—Illustrations have been published † of the appliances devised by Bradbury for sharpening the bits of rock drills. They consist of a number of dies and cutters operated by power for shaping and finishing the cutting end of the bit.

Electric Rock Drills.—Illustrations have recently been published ‡ of the Marvin electric rock drill, with an account of its latest performances. In this drill the bit is carried by a plunger which reciprocates in two coils that are fed alternately with currents by three wires connected to a special dynamo, so that there are no moving contacts in the drill. The machines are built in two sizes to drill holes 8 feet by $2\frac{1}{2}$ inches and 20 inches by $1\frac{1}{4}$ inch, and the average work for the larger size is 60 feet in ten hours in hard limestone. A screw feed is used, and the twist bar is placed at the rear end, where there is also a spiral spring buffer to take up and return the energy of the back stroke. The dynamo runs at 350 revolutions, and gives a current of 130 volts. The coils in the drill are wound with copper wire of square cross section insulated with mica, and are not liable to be injured by heat.

Ancient Mine Pumps.—According to G. Vieria,§ the working of the iron mines of Chateauverdun dated back to the fourteenth century. Recent explorations have uncovered the ancient works, and in them were found the remains of pumping machinery described in Dietrich's work on the "Mines, Forges, and Salt Works of the Pyrenees," published at Paris in 1786. Other similar machines have been found, some of

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* *American Manufacturer*, vol. lviii. p. 51.
† *Engineering and Mining Journal*, vol. lxi. p. 325.
‡ *Ibid.*, vol. lx. pp. 492–493.
§ *Annales des Mines*, vol. viii. pp. 106–121.

which were in a fair state of preservation. The pumps were of wood, and the pistons were packed with leather. The complete installation seems to have included 35 or 36 pumps, of which 21 have been found. The pumping had been performed by man power. Each pump was provided with levers worked by four men, so that when the whole installation was at work it must have taken 144 men to operate it. At present this ancient plant is replaced by a single pump of the plunger pattern, 7 inches in diameter, 4 foot stroke, working under a head of 138 feet.

Inflammable Gas in Iron Mines.—Lodin [*] has collected the instances recorded of the occurrence of inflammable gas in metal mines, quoting largely from the memoirs on the same subject previously published by B. H. Brough [†] and by C. Le Neve Foster. [‡] Among other instances, the gas explosions in the mines of pisolitic iron ore in Alsace are referred to.

History of the Rancié Mines.—M. Villot [§] has published a lengthy history of the Rancié iron mines in the Pyrenees, which have been worked from a very early date up to the present time. The mines have been worked under special administrative conditions since the end of the thirteenth century, and the author's memoir forms an interesting contribution to economic science. The earliest record of the Rancié mines is Roger Bernard's map, dating back to 1293.

III.—MECHANICAL PREPARATION.

The Magnetic Separation of Iron Ore.—C. M. Ball [||] describes a number of plants built and experiments made in magnetic concentration, especially those at the Benson mines in the St. Lawrence county, New York, at the Jayville mine in the same district, and at Mineville, in Essex county, where Messrs. Witherbee, Sherman & Co. carried out a series of expensive experiments. The importance of these may be judged by

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[*] *Annales des Mines,* vol. viii. pp. 40–105.
[†] *Transactions of the North of England Institution of Mining Engineers,* vol. xxxviii. p. 59 ; *Journal of the Iron and Steel Institute,* 1889, No. II. p. 331.
[‡] " A Text-Book of Ore and Stone Mining," 1894, p. 476.
[§] *Annales des Mines,* vol. ix. pp. 205–268.
[||] *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting).

the fact noted in the paper, that at a moderate estimate the ore-crushing capacity of existing plants located in the Adirondack region of New York, and in New Jersey and Pennsylvania, is sufficient to make more than 1,000,000 tons of high grade concentrates per annum.

H. S. Chase * describes experiments carried on in magnetic separation at the Cranberry mines, in Mitchell county, North Carolina, with results believed to be encouraging, although they have been suspended for a time on account of unfavourable conditions in business. The recent revival in the iron trade, however, may cause a renewal. The paper is accompanied by a table giving analyses of a number of magnetic ores from North Carolina and Tennessee. The author says that the problem presented by these ores, already of Bessemer quality, with only silica to contend with, is very different from that of many eastern ores carrying apatite or pyrites. The low percentage of iron, and the large percentage of silica, render the southern magnetites costly to crush ; but it is fortunately not necessary to crush fine in order to eliminate sufficient of the silica to make the product marketable locally under normal conditions and prices. From these experiments two apparent conclusions may be drawn : 1. That emphasis should be laid upon careful washing, screening, and sizing, rather than upon fine crushing. 2. That each size of material should be concentrated separately upon suitable magnetic separators, giving as a total result a Bessemer concentrate averaging from 50 to 60 per cent. of iron, and of a size sufficiently coarse for furnace-burden without other mixing.

T. Robins † describes the use of indiarubber-covered duck belts as conveyors in magnetic separating plants and elsewhere. After experimenting with the sand-blast, he was enabled to find the most suitable covering composition, and to proportion the thickness so that it was greater in the centre and less at the sides, with the result that the belt wore more equally and lasted longer. To support the carrying side of the belt flat or tapered rollers are condemned, and three rollers are recommended, the centre one horizontal, and the side ones inclined at 45°. Flat rollers are used on the return side. The belt should be driven from the delivery end. The average speed in use is 300 feet per minute, but the author prefers 450 feet on the level, and 650 feet or so on an incline. The thickness of the rubber cover should depend on the weight of the material, and should not be less than $\frac{1}{4}$ inch at the centre, tapering off to $\frac{1}{16}$ or $\frac{1}{8}$ inch for material over 50 lbs. per cubic

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* *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting).
† *Ibid.* (Pittsburgh Meeting).

foot. Most wear occurs at the loading point, so the material should be directed on to the belt by a shoot at about the same speed as the belt is travelling. When charging rough material from a breaker, an ingenious device is to place a screen over the shoot, so that the finer stuff falls through and slides down on to the belt, forming a bed for the coarser stuff to fall upon. Dust-proof compression grease cups are recommended for lubricating.

Unloading Iron Ore.—Some illustrations have been published * of plant at Ashtabula, Ohio, for unloading iron ore vessels, and depositing the material into railway trucks or on to storage piles. Each machine consists of a long bridge-like structure carried on two supports. These supports run on tracks parallel to the dock wall, and are 180 feet apart. A cantilever extension on the land side is 88 feet long, and a movable apron over the ship is 34 feet long. With eight machines, vessels carrying 2500 tons have been discharged into trucks in eleven hours.

Ore Sampling.—D. W. Brunton † has recorded a series of investigations and experiments made with the object of determining the fineness to which crushing must be carried in order to obtain results within an allowable limit of error when sampling ores. His researches appertain to gold and silver ores, but some of his conclusions may be applied to other ores—iron ores, for instance—in which apatite occurs. The fineness to which the ore must be crushed depends on the bulk of the sample, on the relative proportion between the value of the richest mineral and the average value of the ore, on the specific gravity of the richest mineral, and on the thoroughness of the mixing. The principal error in sampling arises from the use of screen cloth irregularly spaced and partially worn, and from cutting samples down too far without crushing. The samples should be recrushed after each successive cutting down, so that there may be a nearly constant ratio between the weight of the sample and that of the largest particle contained therein. Numerous tables of the results obtained are given, and diagrams of curves are given for determining the fineness of crushing necessary, with a range of diameters from 1 inch to 6 inches, and 0·0025 to 1 inch.

* *Iron Trade Review*, vol. xxix. No. 3, pp. 8-9.
† *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting, 1895). Advance proof.

IV.—*METALLURGICAL PREPARATION.*

Calcining Iron Ore at Allevard.—H. Wedding* describes the calcination and magnetic separation of the spathic iron ore at Allevard in France. The processes comprise hand separation, separation according to size by screening, calcination, separation of the ores from worthless material by means of magnets, mixing the ore with lime, and moulding into bricks. Detailed drawings are given of the kilns and of the magnetic dressing plant.

* *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses,* 1895, pp. 368-382, with four plates.

REFRACTORY MATERIALS.

The Seger Scale.—H. Seger * and E. Cramer observe that Dinas firebricks were originally made from the Dinas rocks of South Wales, which consist of a pure quartz. This is made into bricks with the aid of from 1 to 2 per cent. of lime as a binding material. In Germany similar rocks are met with, and similar bricks are made, to which apparently the same name is given. To be able to distinguish properly between the bricks of different origin it is necessary to bear in mind the requirements which good Dinas bricks fulfil. They must be strong, possess a high melting point, and should not shrink. Their volume must remain as constant as possible under varying temperature conditions, and they must contain a high percentage of silica. The authors proceed to a consideration of the methods of testing which are in vogue. To determine the strength of the brick it is usually considered adequate to strike it with a hammer and to note the effect. If it gives out a sharp sound, the brick is considered satisfactory, the relative degree of goodness being held to vary with the height of the note. Actual mechanical tests would doubtless give better results. To ascertain easily and rapidly the relative degree of infusibility which the brick possesses, it suffices to heat small splinters of the brick, some 20 to 30 millimetres in length and about 5 in thickness, in a Deville furnace. This latter is nothing more than a hollow cylinder of very fire-resisting material, resting on a perforated wrought iron plate through which air can be forced. Retort carbon is the best fuel to use, and very high temperatures can be attained. To determine the temperatures the Seger scale can be used. The various members of this scale consist of tetrahedra made of mixtures of clay and sand, each having a different melting point to that of any other member of the series. Assuming the temperature of dark redness to be 710° C., No. 022 of the scale has this melting point; No. 010 has the melting point of silver, 950° C. The No. 1 of the series corresponds to the melting point of an alloy of nine parts of gold with

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* *Stahl und Eisen*, vol. xv. pp. 1084-1087

one of platinum, estimated to have the melting point of 1150°. For No. 20 a melting point of 1700° is assumed, and the other members of the series have melting points which vary gradually between these limits. The composition and melting point of each member of the Seger series is given, and of these the following are a few :—

No. of Seger Scale.	Chemical Composition.			Melting Point, Degs. C.
022	$\begin{cases} 0.5\ Na_2O \\ 0.5\ PbO \end{cases}$	· ·	$\begin{cases} 2\ SiO_2 \\ 1\ B_2O_3 \end{cases}$ · · · ·	710
015	$\begin{cases} 0.5\ Na_2O \\ 0.5\ PbO \end{cases}$	$0.6\ Al_2O_3$	$\begin{cases} 3.2\ SiO_2 \\ 1.0\ B_2O_3 \end{cases}$ · · · ·	850
011	$\begin{cases} 0.5\ Na_2O \\ 0.5\ PbO \end{cases}$	$0.8\ Al_2O_3$	$\begin{cases} 3.6\ SiO_2 \\ 1.0\ B_2O_3 \end{cases}$ · · · ·	930
010	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$\begin{cases} 0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3 \end{cases}$	$\begin{cases} 3.50\ SiO_2 \\ 0.50\ B_2O_3 \end{cases}$ · · ·	950
001	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$\begin{cases} 0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3 \end{cases}$	$\begin{cases} 3.95\ SiO_2 \\ 0.05\ B_2O_3 \end{cases}$ · · ·	1130
1	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$\begin{cases} 0.2\ Fe_2O_3 \\ 0.3\ Al_2O_3 \end{cases}$	$4\ SiO_2$ · · · ·	1150
10	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$1\ Al_2O_3,\ 10\ SiO_2$ · · · · ·		1410
15	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$2.1\ Al_2O_3,\ 21\ SiO_2$ · · · ·		1555
20	$\begin{cases} 0.3\ K_2O \\ 0.7\ CaO \end{cases}$	$3.9\ Al_2O_3,\ 39\ SiO_2$ · · · ·		1700
28	$Al_2O_3,\ 10\ SiO_2$ · · · · · ·			1940
30	$Al_2O_3,\ 6\ SiO_2$ · · · · · ·			2000
35 (Kaolin)	$Al_2O_3,\ 2\ SiO_2$ · · · · ·			2150
36 (Clay slate)	$Al_2O_3,\ 2\ SiO_2$ · · · · ·			2180

All the intermediate members of the series are similarly described. It will be seen that in the members of the series from 022 to 011 soda and lead oxide are added for fluxing purposes. The difference between the various numbers consists in each of the lesser numbers containing 0·1 more of alumina and 0·2 more of silica. The mixtures from 010 to 001 contain varying percentages of boric acid. The numbers from 4 to 27 contain the same bases, but the alumina and silica increase gradually. The numbers 28 to 36 are pure alumina silicates. A photograph shows four of these mixtures, in the form of cones of different melting points, which have been submitted to a high temperature. One has nearly melted down, a second is considerably fused, while the third shows signs of incipient fusion, and the fourth has not been affected. The third would, therefore, represent the melting point.

The authors describe how the melting point of Dinas bricks can be compared with those of the members of the Seger series, and then describe how the degree of expansion of the bricks on heating may be ascertained. The method simply consists in a determination of the

specific gravity of the brick mass before being subjected to heat, and afterwards. Five samples of Dinas brick were tested, and these had the following percentage compositions :—

Brand.	Silica.	Alumina and Ferric Oxide.	Lime.
Stella	95·40	1·40	3·20
Allen	97·40	1·49	1·11
Lowood	96·80	2·23	0·97
Lütgen I.	96·24	2·36	1·40
Lütgen II.	96·54	2·03	1·43

The melting points of all were approximately the same, being higher than that of No. 34 of the Seger scale, but lower than that of No. 35.

Fireclays.—According to C. Ferry * about 3 per cent. of hydrated ferric oxide will give to a wet plastic clay an intense red colour, but the redness is no indication of its refractory properties. These depend upon the proportions of other materials that also act as fluxes. A certain percentage of iron oxide is advantageous, as it renders the brick hard and tough, and seldom makes it more brittle.

C. Ferry † again deals with the capabilities of the New Jersey clays, and to the inefficient results that have occurred in their use for the manufacture of firebricks, especially "bung bricks." By suitably tempering the bricks will withstand fusion, but they are still liable to disintegration in many furnaces.

According to J. A. Holmes,‡ the Appalachian Mountains attain their greatest development in North Carolina, and as one result of the disturbances which produced them, there are numerous dykes or veins of coarse granitic materials. Some of these are mined for mica, others for kaolin. One of these, near Webster, in Jackson county, is 300 feet wide and half a mile long, and is extensively worked; but there are numerous others, some of which are mentioned. Through many parts of the mountain and the Piedmont plateau regions there are extensive deposits of clay produced by the denudation of the rocks. These are of various ages and characters; many are probably recent, and due to local action. The deposits most used for the manufacture of firebrick are worked along the entire coastal plain of the South Atlantic States.

* *Iron Age*, vol. lvii. p. 182.
† *Ibid.*, p. 698.
‡ *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting, 1895). Advance proof.

Gas Explosions in Mining Fireclay.—Several instances are given in which the mining of seams of fireclay has been found to give rise to the escape of combustible gas, with the result that explosions of considerable violence ensued. One such explosion is related in connection with the Malakoff quarries near Paris. Here a miner, having reached the bottom of an 80-foot shaft, was about to enter a drift with a naked light when an explosion ensued of such violence that he was blown right up the shaft to the surface. It is thought that the origin of the gas is due to the decomposition of the wood used as the supports in parts of the pits which have been worked out and abandoned workings. The gas escapes with noise, but the emission soon ceases. It is evidently contained under pressure in spaces in the clay. The characteristic smell of the gas, too, is such as to leave no doubt of its origin.

The outbursts of inflammable gas met with in the Bollène fireclay quarries are described by Oppermann,[*] those in the Malakoff quarries, by Humbert,[†] and those in Belgium by F. Roberti-Lintermans. [‡]

The Composition of Firebricks.—A. Heintz [‡] observes that to judge of the value of a firebrick by its analysis alone is inaccurate, despite the fact that it has become usual to stipulate for a certain percentage of alumina. Pure refractory clay, as it occurs in nature, has the higher fire-resistance the greater the percentage of $Al_2O_3,2SiO_2$. If it consists of pure clay, it will contain 53·9 per cent. of silica and 46·1 of alumina, but such a material is rare. Generally other bases and silica are contained in it, and it is these which so largely affect the value of the material. To stipulate for a certain percentage of alumina is all right so far as it goes, but other points have also to be considered. Thus the physical character of the material is of great importance, and the question of the relative porosity of the material has to be taken into consideration as well as other similar points.

C. Ferry [§] shows how the term "high silica firebrick" has been misused by applying it to bricks which only contain 50 or 60 per cent. of silica, whereas they should have 85 to 90 per cent. It is pointed out that burnt rock or flint fireclays are not even approximately pure silica, but may contain a quantity of alumina approaching the 35 per cent. of pure kaolin, and are therefore useless in the manufacture of siliceous brick.

[*] *Annales des Mines*, vol. viii. pp. 5–18.
[†] *Ibid.*, pp. 19–25.   [‡] *Ibid.*, pp. 26–28.
[‡] *Chemiker Zeitung*, vol. xx. p. 177.
[§] *Iron Age*, vol. lvi. pp. 734–735.

C. Ferry * discusses the testing of firebricks, and shows that simple tests for refractory properties made by the maker are not of much value to the user, as they do not include the conditions under which the brick is employed.   The users' tests are, however, often most defective.   It is a common practice to place a single brick on the bridge of a furnace and then to note its behaviour; but the result is often valueless, because fused matter from the roof drops on to it and slags it away.   It is best to make a preliminary test by building the brick into the top course of the bridge wall, so that it has two surfaces exposed.   It is then under the same conditions as the adjacent bricks, and if it acts satisfactorily, part or whole of the roof may be lined with a sample of 500 or 1000. Great care is necessary in making these tests.

Chamotte is the name given to clay which has been burnt with a view to being subsequently employed in its burnt form as an addition to unburnt clay in the manufacture of earthenware articles; the chamotte bricks so largely employed for furnace construction are typical of this. It has hitherto been thought that the burning of clay for this purpose is comparatively modern, but a careful investigation of some articles from Olympia exhibited at the museum at Berlin, and dating from the sixth century B.C., has shown that chamotte was employed in their manufacture.   H. Lütgen † points out that the chamotte industry, therefore, instead of being a modern invention, was, though subsequently forgotten, in use at least 2500 years ago.

Fire-Resisting Materials in the Caucasus.—H. H. Niedenführ ‡ observes that firebricks are difficult to obtain in the Caucasus.   Suitable fireclays are nearly absent, and such as there are, are difficult of access. There is only one important firebrick works, and that is at Baku, and its further development is rendered difficult for the above reason, and on account of transport charges generally.

The Diesener-Janitz Brick-Kilns.—It is stated by Janitz § that experience has shown a great saving in fuel when using these annular kilns in burning firebricks.   Burning to No. 14 of the Seger scale, about 50 per cent. was saved as compared with a gas kiln of the same dimensions.

 * *Iron Age*, vol. lvi. pp. 885–886.
 † *Thon-industrie Zeitung; Stahl und Eisen*, vol. xv. p. 974.
 ‡ *Chemiker Zeitung*, vol. xx. p. 269.
 § *Ibid.*, p. 177.

Limestones and Dolomites.—B. J. Harrington [*] gives the results of analyses of limestones and dolomites from eighteen localities in Canada.

C. von John and C. F. Eichleiter [†] give the following results of analyses of Austrian and Hungarian limestones, dolomites, and magnesites :—

Locality.	Calcium Carbonate.	Magnesium Carbonate.	Ferric Oxide and Alumina.	Insoluble Residue.
Stramberg	99·48	0·29	0·21	0·22
Kaltenlentengeben . . .	69·07	3·17	3·36	23·04
Sainixa, Hungary . . .	62·36	2·12	4·70	29·50
Brunn	94·00	1·72	...	2·12
Brunn	96·90	1·55	...	0·68
Brunn	89·50	1·87	...	5·20
St. Veit (dolomite) . . .	55·50	44·41	0·08	0·01
Veghles (dolomite) . . .	50·30	40·03	1·72	6·72
Horazdovitz . . .	84·79	0·42	0·61	13·61
Vrbovako (dolomite) . .	57·68	41·93	0·48	0·10
Stangenthal	95·50	1·28	0·32	2·80
Satteles	95·20	...	1·98	2·02
Koneprus	99·39	0·67	0·09	0·05
Karlstein	94·64	5·36	0·14	0·48
Korno	94·58	2·84	0·49	1·44
Karlstein	79·00	14·53	0·90	4·27
Travnik	99·50	...	0·32	0·22
Lindewiese	96·37	...	...	2·74

Bauxite.—Several examples of bauxite from Floyd and Bartow counties, in Georgia, were exhibited at the Atlanta Exposition. The material from the latter is washed in a log washer and dried in a Davis-Colby kiln. [‡]

Plumbago Crucibles.—Some suggestions for the use of plumbago crucibles have recently been published. [§] They should be stored in a warm dry place, and should be heated at 212° F., or a little over, before use, to thoroughly dry them. If the crucible is. large it should be set upside down over a black fire. New crucibles should be used in new slow fires, and crucibles glazed from use in the hottest fires. The tongs should fit well, and preferably should grip the crucible below the bulge. Sulphurous coal is pernicious, and a reducing flame is to be preferred. The crucible should be set down gently in a dry place, and should be completely emptied before cooling. The charge should not be rammed in too tightly, or its expansion will tend to crack the crucible.

[*] *Canadian Records of Science*, vol. vi. pp. 27-32.

[†] *Jahrbuch der k.k. geologischen Richestanstalt*, vol. xlv. p. 16.

[‡] *Engineering and Mining Journal*, vol. lx. p. 296.

[§] *Iron Trade Review*, vol. xxix. No. 6, p. 11.

Austrian Graphites.—C. von John and C. F. Eichleiter [*] give the following results of analyses of Austrian graphites :—

Locality.	Carbon.	Ash.	Water.
Pozega	14·25	78·24	7·51
Pozega	13·09	80·20	6·71
Trieben	80·42	11·20	8·50
Kallwang	22·41	76·06	1·34
Heiligenblut . . .	34·62	58·95	6·43
St. Lorenzen . . .	42·72	54·30	2·98
Reichmanngrube . . .	70·04	26·50	3·46

The Specific Heat and Boiling Point of Carbon.—The following results have been obtained by J. Violle [†] :—

I. Above 1000° the mean specific heat of graphite increases regularly with the temperature in accordance with the formula

$$C^{ot}=0·355+0·00006^{t}.$$

II. The heat given out by 1 gramme of solid graphite in cooling from the temperature of volatilisation to 0° is 2050 calories.

III. The boiling point of carbon is therefore 3600°.

Fusibility of Bottom Sand.—C. Ferry [‡] discusses the applicability of various kinds of sand as a material for lining the bottoms of furnaces, especially those used for reheating. For these furnaces, the chief characteristic is that it must set firmly, but it must not be too fusible. If it does not set it is liable to adhere to the iron, and so is rolled into the material as it passes through the mill, and this occurs every time the furnace is patched. The true value of a sand for these purposes is entirely dependent on its refractory properties, and these only partially depend upon the chemical composition. Coarseness of grain renders the sand less fusible, so that it sets more slowly, or requires a greater heat. The percentage of silica, therefore, is not the only factor to be considered. Of two sands with the following composition—

SiO₂.	Al₂O₃ + Fe₂O₃.	CaO.	MgO.	H₂O.	Total.
91·55	7·40	0·51	0·11	0·61	100·18
91·47	4·88	0·21	none	3·61	100·17

the first gave excellent results, but the second would not set. This result is largely due to the difference in the amount of fluxes present, and the influence of these is considered at some length by the author, who is of the opinion that alumina cannot be regarded as of much value in this respect.

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlv. p. 9.
† *Comptes Rendus de l'Académie des Sciences*, vol. cxx. pp. 868–869.
‡ *Iron Age*, vol. lvi. pp. 1264–1265.

FUEL.

CONTENTS.

I.—CALORIFIC VALUE.

The Calorific Power of Coal.—G. Arth [*] observes that there are various views as regards the practical application of the Dulong formula for calculating the calorific value of a fuel. While, according to Bunte, the values obtained by this method differ but little from those obtained by direct determination, Scheurer-Kestner, on the other hand, found that the results obtained by the two methods differed widely, up to as much as 6 per cent. The author has analysed seven varieties of coal, and calculates their calorific values according to the formula—

$$Q = \frac{34500(H + \frac{1}{8}O) + 8080C + 2162S}{100}.$$

M. Mahler examined the coals calorimetrically, and an examination of the results showed differences which did not exceed 2 per cent.

E. Goutal [†] proposes to determine the calorific power of coal by means of the formula—

$$Q = 8150 \, C + A \text{ (volatile matter).}$$

A being equivalent to—

13,000 for volatile matter between 2 and 15 per cent.
10,000	,,	,,	,,	15 and 30	,,
9,500	,,	,,	,,	30 and 35	,,
9,000	,,	,,	,,	35 and 40	,,

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[*] *Bulletin de la Société Chimique*, vol. xiii. p. 820.
[†] *Revue de Chimie Industrielle*, vol. vii. No. 75.

The fixed carbon includes, of course, the coke, less ash, and the volatile matters are assumed as free of hygroscopic moisture. Compared with the results of the Mahler determination this formula works out fairly well in most instances.

	Calculated.	Determined.
Pennsylvania anthracite	7494	7484
La Mure anthracite	7448	7504
Kebao (Tonkin) anthracite	7712	7773
Commentry anthracite	7709	7850
Blanzy (Ste. Barbe) anthracite . .	7757	7773
Grand'Combe anthracite	7760	7850
Le Creusot anthracite	8371	8404
Aniche, Ferdinand seam	8339	8426
Semi-caking coal, Grand'Combe . . .	8396	8371
Semi-caking coal, Roche La Molière . .	8397	8417
Caking coal, Lens, No. 8 pit	8670	8614
Caking coal, Roche La Molière . . .	8525	8482
Caking coal, St. Etienne	8476	8392
Caking coal, Carmaux	8300	8380
Caking coal, Anzin	8026	8051
Gas coal, Béthune	8250	8210
Gas coal, Lens	8371	8395
Gas coal, Firminy	8172	8161
Gas coal, Montrambert	8276	8268
Gas coal, Commentry	7947	7870
Gas coal, Montvie	7747	7798

For lignite and coals of lignitic tendency, however, the method is admittedly less exact; for lignite coal from Decazeville, for example, the calculated value is 7780 calories, against 7408 by direct determination, and it is therefore considered advisable to limit the use of the formula to coals containing below 35 per cent. of volatile matter (free from moisture).

W. A. Noyes, J. R. McTaggart, and H. W. Craver [*] discuss the determination of the heating effects of coal. The work described was undertaken for the purpose of comparing the results obtained with Hempel's calorimeter with those calculated from analyses and those obtained by Berthier's test. Six specimens of representative Indiana coals were used, as follows : Brazil block from Brazil, Lancaster block from Clay Co., Shelburn coal from Shelburn, two samples from the mines of the New Pittsburg Coal Company at Alum Cave, and a sample of mine screenings used in the shops of the Rose Polytechnic Institute. The first two are known locally as " block " coal, and are non-caking. The others are known as bituminous, and are caking coals.

* Journal of the American Chemical Society, vol. xvii. pp. 843–849.

The following table gives the results of the analyses and other determinations :—

	New Pittsburg. A.	New Pittsburg. B.	Lancaster.	Brazil.	Shelburn.	Shop.
Moisture	6·83	5·89	12·66	8·98	8·63	2·36
Volatile combustible matter . .	39·92	42·23	37·44	34·49	38·82	31·11
Fixed carbon	39·93	40·40	47·22	50·30	43·45	42·44
Ash	13·31	11·48	2·68	6·28	9·05	24·09
Carbon	62·88	65·26	71·41	70·50	66·86	57·32
Hydrogen	5·07	5·17	5·56	4·76	5·30	4·56
Nitrogen	1·01	1·17	1·54	1·36	1·50	1·44
Oxygen	13·06	13·25	18·42	16·29	15·69	9·93
Ash (corrected)	17·98	15·15	3·07	7·09	10·65	26·75
Sulphur	7·46	5·88	0·62	1·39	2·57	4·25
Iron, calculated	6·53	5·14	0·54	1·22	2·25	3·72
Calories per gramme, calculated C .	5,081	5,272	5,770	5,696	5.402	4,632
Calories per gramme, calculated H .	991	1,011	939	784	962	956
Calories per gramme, calculated S .	161	127	13	30	55	92
Calories per gramme, calculated Fe	103	81	9	19	36	59
Total . . .	6,336	6,491	6,731	6,529	6,455	5,739
Difference, per cent. . . .	+2·6	+1·2	+0·4	−4·6	−1·2	−1·2
Calories per gramme, Berthier's test, factor 268·3 . . .	6,307	6,471	6,831	6,689	6,461	5,726
Difference, per cent. . . .	+2·1	+0·9	+1·9	−2·3	−1·1	−1·4
Calories per gramme, calorimeter .	6,175	6,415	6,703	6,846	6,532	5,806

In discussing the results, it is worth while to notice that, so far as indicated by the agreement of duplicate determinations, about the same degree of uncertainty attaches to the calorimetric determinations and to the litharge test, while the uncertainty of the analysis is about twice as great. It is noticeable that the results calculated from the analyses and those given by Berthier's test agree better with each other than either agree with the calorimeter results.

The Combustion of Coal.—W. Hempel * points out that it is still a common fallacy that carbon burns to CO when an inadequate supply of oxygen is present, and to CO_2 when oxygen is present in excess. Years ago he showed that the supply of oxygen was not the cause of this phenomenon, which is mainly a function of temperature and pressure. Thus at low temperatures carbonic anhydride is produced, with only traces of oxide, while at high temperatures mainly carbonic oxide results, very little carbonic anhydride being formed. Carbon behaves

* *Zeitschrift für Angewandte Chemie*, 1895, p. 729.

in a similar manner to sulphur when burnt under pressure, and while sulphur yields practically solely SO_2 when burnt at ordinary temperatures, much SO_3 is produced when the pressure under which the combustion ensues is a high one. A smoky flame is dependent on its temperature. If the temperature of the flame is high there is but little smoke, while the smoke increases as the temperature drops. In boilers careful stoking can give as complete and as smokeless a combustion on an ordinary grate as on any of the so-called "smokeless" methods of firing the author examined. A very deep fire-bar, deep over its whole length, leads to good results by pre-heating the air before it enters the furnace, with the result also that the bar itself, being cooled down more completely by the incoming air, has a life of greater length. The firing on an ordinary grate may be so performed by shoving back the coal that at the fire-bridge there is practically nothing burning but pure coke, while the composition of the mass of burning fuel varies gradually to that of the fresh coal at the charging doors. In tubular boilers it is possible under very favourable conditions to attain a percentage of 18 of carbonic anhydride in the products of combustion. The greatest transfer of heat is from the hot flame, and it is a matter of but little importance whether the products of combustion escape at a temperature of 150° C. or at one of 300° C. A boiler whose products of combustion contain 15 per cent. of carbonic anhydride, and which pass into the stack at a temperature of 300°, will give far better results in practice than another boiler which gives products of combustion containing only 7 per cent. of carbonic anhydride, and escaping at the temperature of 150°. The correct regulation of the air admitted to the boiler while most necessary, is at the same time readily controlled.

Calorimetry.—An improved calorimeter for the application of the method of mixtures in determining specific heats, is described by F. A. Waterman.* Hesehus's ingenious suggestion is acted upon to maintain the calorimeter, after the introduction of the heated body, at a constant temperature by means of cold water instead of measuring the rise of temperature of the calorimeter. This arrangement gets rid of the radiation error, and eliminates the "water equivalent" of the vessel. By dropping the cold water in, stirring is also made unnecessary. The method has been placed by the author upon a footing of equality at least with other methods, but his success may be partly due to other improvements. The body experimented upon is heated by a coil of wire

* *Philosophical Magasine*, vol. xl. pp. 413–421.

conveying a current, and surrounded by ice. The initial temperature of the body may thus be regulated by simply maintaining the current at a certain strength, and this temperature can be kept constant for five or six hours together to within 0·01° C. The cold water is contained in a copper vessel having the shape of an inverted cone, surrounded by ice. The body is then plunged into a silver calorimeter surrounded by the bulb of a delicate air thermometer indicating a difference of temperature of 0·01° C. In this manner the ice cannot melt away and leave a free space round the vessel. The water-dropping arrangement and the electric heater are mounted on vertical axes in such a manner that they can be quickly swung into position just over the calorimeter. After the heated solid or liquid has been dropped in, the water-dropper is set to work, at first rapidly, and then slowly, until the body has assumed the original temperature of the calorimeter. For bodies of the same weight and the same initial temperature, the specific heat is then measured simply by the amount of ice-cold water necessary to cool them to the temperature of the room.

Carpenter [*] describes a new calorimeter for determining the fuel value of coal. The coal is burnt by the introduction of oxygen after electric ignition in a closed chamber. The chamber is in the interior of a water-vessel, the contents of which are in connection with a thermometer tube, on which the increase in temperature is read.

Pyrometry.—A modified form of pyrometer, dependent on the method of mixtures, has been patented by G. Braubach.[†] It consists of an inner measuring vessel and a protecting outer one, air isolation being used. The inner vessel rests on a ring of cork, affixed to the bottom of the outer enclosing vessel. It has a conical mouthpiece, and a tube to contain the thermometer. The method of manipulation does not differ from that of other pyrometers of this kind.

L. Holborn and W. Wien [‡] discuss the use of the increased resistance of platinum and the use of a thermal junction of platinum and platinum-rhodium, and state the superiority, under different conditions, of the latter method.

Descriptions have been published [§] of the various methods of measuring high temperatures. The thermo-electric pyrometer of Le Chatelier and the pyrometric telescope of Cornu are specially referred to.

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[*] *American Machinist*, 1895, p. 870, with three illustrations.
[†] *Stahl und Eisen*, vol. xvi. pp. 207-209, two illustrations.
[‡] *Annalen der Physik und Chemie*, vol. lvi. pp. 360-396.
[§] *Portefeuille économique des Machines*, 1896, pp. 6-11, with three illustrations.

The subject of the determination of temperature by the aid of thermo-elements is discussed by Quincke.[*]

The Le Chatelier pyrometer is again described and its value discussed.[†] The points to be noted when using it are considered, and it is pointed out that when it is desired to use it for very high temperatures, the material used for isolating the wires from each other may consist of the following :—6 parts of Rakonitz clay slate and 1 part of chemically pure alumina, calcined at the temperature of No. 20 of the Seger scale; to 7 parts by weight of this are added 3 parts of Vallandar clay, and the glaze used corresponds to $\left.\begin{array}{c} 0\cdot3\ K_2O \\ 0\cdot7\ CaO \end{array}\right\rangle 1\cdot5\ Al_2O_3,\ 10\ Si\ O_2.$ The above mixture has a higher melting point than has No. 36 of the Seger scale.

The pyrometer devised by Uehling and Steinbart is again described,[‡] and it is shown that while it does not give as accurate results as other methods, yet it appears to be fully adequate for the purpose for which it was designed, that is for measuring blast-furnace temperatures.

II.—COAL.

The Coalfields of England and Wales.—In his annual report for the year 1895, Sir Archibald Geikie,[§] Director-General of the Geological Survey, gives the results that have been obtained in the revision of the surveys of the coalfields of South Wales, of Warwickshire, of North Staffordshire, and of the North of England. In the North Staffordshire coalfield one of the most interesting features observed is the curvature of the coal seams met with in the workings of the Podmore Hall Colliery. The mining plans disclose the curious fact that two parties of pitmen, descending by two sets of shafts, were found to be working vertically one under the other in the same coal seam without being aware of it until, on comparison of plans, it was ascertained that the coal seam lay folded, like the letter U placed on its side, but without the intervention of any fault. This remarkable curvature is believed to be connected with the anticlinal flexure which produces an east and west inclination. The strata along the up-thrust or bend are so steep that the so-called

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 101-102.

† *Chemiker Zeitung*, vol. xx. p. 177.

‡ *Zeitschrift für Instrumentenkunde*, vol. xv. p. 451 ; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 98; see also *Journal of the Iron and Steel Institute*, 1894, No. II. p. 309.

§ "Forty-second Report of the Department of Science and Art," 1895, pp. 267-300.

plans of the workings are more of the nature of elevations, the coal being got vertically in steps rather than horizontally in layers.

The Depth to Productive Coal Measures.—C. E. De Rance [*] discusses the information gained since the Report of the Royal Coal Commission in 1869 on the subject of the depth to productive coal measures between the Warwick and Lancashire coalfields. The author concludes as follows : In the light of these investigations it will be seen that the late Sir Andrew Ramsay underestimated the depth to commercial coal seams in the Midland counties, more especially in the area of maximum development of the Trias formation ; but the whole gist of the accumulated information tends to show the extreme variety of the conditions obtaining at any one point ; further, that each small area must be judged and considered on its merits, and that without actual boring the judgment of the expert, however experienced, may be at fault. It certainly might have been supposed, looking to the occurrence of quasi-Permian beds in Denbighshire, North and South Staffordshire, and Warwickshire in very considerable force, that they would have been present in the Sherbrook Valley, Rugeley, but there 327 feet of Bunter pebble-beds rest direct on coal measures, and at the Huntingdon pumping stations of the South Staffordshire waterworks the same conditions obtained. From these series of facts it appears that three series of rocks intervene between the Keuper marls and the commercial coalfields of Lancashire and Warwickshire. Proceeding from north to south, the Triassic group alternate from the base upwards, the Bunter series being absent, the basement beds of the Keuper, though present, being only a few inches thick, the waterstones and Keuper marls being much less than half their thickness. Proceeding from north to south, the true Permian is also found to be governed by the same conditions, and none occur south of Dr. Hull's barrier in Central Cheshire ; on the other hand, the coarse sandstones and conglomerates, the variegated and purple marls, with included bands of *Spirorbis* limestone, are constantly absent, proceeding from south to north of Dr. Hull's barrier, the Triassic pebble-beds constantly resting direct on the Middle coal measures, the extensive denudation that occurred with the first appearance of the red dust at the close of the Carboniferous period (ascribed by Mr. Binney to volcanic origin), continuing in great force through the whole of the period between the formations of the upper commercial coal seams and the deposition of the Triassic pebble-beds.

[*] *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 244–258.

The Silkstone and Beeston Seams.—H. St. J. Durnford * gives
some notes on the sinking of the No. 1 Pit at the Ackton Hall Colliery,
with special reference to the thinning out of the Silkstone and Beeston
seams.   In the majority of the pits in the vicinity of Pontefract, the
Silkstone 4-feet or Johnny coal seam is found 100 to 120 feet above
the Silkstone seam.   In this sinking, at a depth of 1724 feet, a 29-inch
seam was met, and at 1808 feet an 18-inch seam.   These are supposed
to correspond to the seams mentioned above, and a 17-inch seam at a
depth of 2126 feet is supposed to be the Beeston seam.   A detailed
section is given showing the strata passed through between the depths
of 1206½ and 2144 feet.   Workings were started north and south from
a temporary landing at 1808 feet to a distance of 900 feet, but the seam
did not improve.   On the north side a borehole was then put up to find
the seam which had been proved 90 feet above in the shaft, and the
seam was then found to have thickened to 6 feet, with a 14-inch parting
in all appearance like the true Silkstone seam.

The South Yorkshire Coalfield.—F. Baker † gives a general
description of the South Yorkshire coalfield, and in it deals more or less
popularly with the scenery and the formations.   A sketch map and some
sections are appended.

Boring at Apperknowle, near Sheffield.—G. E. Coke ‡ describes
the boring made to discover if there were coal below the black-shale coal
seam, which was becoming worked out in the Unstone Valley.   No
seam above this coal could be worked at a profit, so the boring was
started in 1893, and carried to a depth of 999½ feet from the surface.
A detailed section of the strata passed through is given, but no coal of
any value was found.   The diamond drill was used, and the work was
done from the bottom of the Apperknowle Colliery, near Sheffield.   This
allowed 390 feet of rod to be withdrawn in three minutes without un-
screwing, and to be lowered in five minutes.

The Wyre Forest Coalfield.—T. C. Cantrill § gives a general
account of the geology of the Wyre Forest district, to which the attention
of mining men has been called by the successful sinking on the Tip House

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* *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 444–454.
† *Proceedings of the Cleveland Institution of Engineers*, 1896, pp. 105–117.
‡ *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 483–491.
§ *Colliery Guardian*, vol. lxxi. p. 351.

Farm, near Kinlet, where a coal seam, about 5 feet thick, has been recently proved at a depth of 300 yards.

The Southern Ayrshire Coalfields.—R. W. Dron * deals with the geology of the portion of the Ayrshire coalfields south of the Kilmarnock and Irvine coalfields. The formation of this district is a basin having its centre near Mauchline. The central part is a well-defined series of Permian or new red sandstone rocks, surrounded by the outcrop of volcanic rocks of Permian age. Immediately underlying are the red sandstones of the Carboniferous age. The black-band and clay-band iron-stones are, as elsewhere, regular indications of the coal measures. The Millstone grit is not so regular in Ayrshire as in some other parts of the country. Both it and the carboniferous limestone are thickest at Muirkirk, and thin out towards the western side of the basin. The calciferous sandstone does not attain great thickness, and does not contain shale or coal. The author then gives details of the various districts, including Muirkirk and Glenbuck, Mauchline and Sorn, Symington and Dundonald, Annbank, Cumnock and Lugar, New Cumnock and Dalmellington, and Girvan. Sections of the various districts are given, and a geological map is appended. It is considered that in the future the output of coal from Ayrshire will be greatly increased, but this will be done by opening up undeveloped districts, as no great increase can be expected from existing pits.

The French and English Coalfields.—In a borehole at Gravelines, on the northern coast of France, carboniferous rocks were met with at a depth of 1230 feet, and even coal was found. This was not anticipated for at least another 82 feet. At Dover the carboniferous series was met with at a depth of 1174 feet. It would appear, therefore, that the Dover carboniferous series continues under the Channel as far as France, as Bertrand and others have suggested. Another borehole near Offenkerque is still in hard chalk at a depth of 820 feet.†

M. Chapuy ‡ has published a geological description of the Valenciennes coal basin.

Analyses of Austrian Coal—In the report on the analyses carried out in the laboratory of the Imperial Geological Survey, C. von John

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* *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 378–388.

† *Echo du Nord; Glückauf*, vol. xxxii. p. 149.

‡ *Annales des Mines*, vol. viii. pp. 192–217.

and C. F. Eichleiter * give the results of analyses of 120 samples of coal from various localities in Austria and Hungary.

Anthracite from Tirgu-Jiu in Roumania gave on analysis—

Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Water.	Ash.
86·03	1·00	0·52	1·43	2·90	8·12

The ash of this anthracite consisted of—

SiO₂.	Fe₂O₃.	Al₂O₃.	CaO.	MgO.	S.	P.
46·34	29·22	17·26	2·75	4·05	0·25	0·38

The Ruhr Coalfield.—M. Schulz-Briesen † describes the stratigraphy of the seams in the Emscher basin of the Ruhr coalfield, with special reference to the uppermost group of seams. His observations are based on the results of the mining operations carried on during 1894.

The Anthracite Deposits of Hanover.—Hanover is but poor in deposits of bituminous coal, but it possesses important deposits of anthracite, having the specific gravity of from 1·6 to 1·7.‡   It is found in the carboniferous formation existing near Osnabrück in the Piesberg.   The Piesberg is a hill rising a few miles to the north-west of Osnabrück. The beds form an anticlinal, and are faulted by a large fault at almost right angles.   The resulting throw is very considerable, and its extent is still unknown.   At the present time four seams of anthracite are being worked, with a total thickness of 8 feet 10 inches, but seven seams are known, with a total thickness of 15 feet of coal in 546 feet of strata. About 600 tons of coal a day is raised.   The method of working is described, and the appliances in use are mentioned.

At the Hanover Mining Congress an important paper was contributed by Richert § on the coal mines of the North German Wealden.

The Brown-Coal Deposits of Hanover.—Very little brown coal is found in Hanover, even less than there is of coal.   It is mined at three places in the south and at one very small pit at Weenzen am Hils in the north, but the last named only raised some 300 tons annually. Possibly brown coal may exist in the Tertiary strata occurring under the Diluvium and met with at several places, but it is not likely that in

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* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlv. pp. 1–9.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliv. pp. 12–54.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 617.

§ *Glückauf*, vol. xxxi. p. 1251.

Hanover the brown-coal industry will ever rise to be one of great importance. The brown coal found in the southern part of Hanover occurs in the Lower Miocene.* At the Steinberg pit near Münden a seam of lignite is divided by one or two partings into two or three beds of from 6 to 7 yards in thickness each. The distance to Münden is about six miles by road, and the roads are bad. This has greatly hindered the advantageous working of this deposit, but now a wire ropeway 4·4 miles in length connects the mine with the Münden railway station.

The Sollinger brown-coal mines are connected by a shorter wire ropeway than the above with the railway station at Volpriehausen. Four seams are mined, varying from 1 to 4 yards in thickness. Between the first and second seam is a parting of fireclay, which is also worked; while a quartz sand occurring between the second and third seams is also mined. With 200 men employed, about 60,000 tons of brown coal is raised annually. The mine is provided with a briquette plant.

At Düderode, in a geological depression $2\frac{1}{2}$ miles in length and rather less than two in width, numerous boreholes have shown the existence of three seams of brown coal. The uppermost is from 5 to 8 yards in thickness and is only covered by a thin layer of earth and soil. The middle one varies in thickness from 15 inches to 6 feet and more, and occurs at a depth of from 5 to 34 yards from the surface. Two hundred feet below this is a third seam. This latter seam is a very thick one, ranging from 49 to 60 feet. It consists of three divisions, separated from each other by clay partings $1\frac{1}{2}$ to 3 yards in thickness. A dark and very plastic clay, impervious to both water and gas, forms both the partings and the roof, while the floor is sand, so full of water that it occasionally has the character of a quicksand. The material composing the two upper seams is earthy and poor in lignite and bitumen, while that of the main seam is a mixture of earth and compact brown coal, rich in bitumen and lignite, together with finely divided pyrites and retinite. Of lignite not infrequently whole tree trunks are found. As mined, the fuel contains from 47 to 51 per cent. of water. Its calorific power is 5640, and 1 kilogramme of the clean dry coal yielded, when distilled at 700° C., 48 per cent. of gas, which burnt with a luminous flame. It contained, in addition to hydrocarbons, 38 per cent. of carbonic anhydride and some carbonic oxide.

Only the main seam is mined. Three shafts have been sunk, the winding shaft being partly tubbed in wood and partly walled. This shaft is 249 feet deep. In 1894 eighty men were employed, the fuel

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 657.

raised amounting to 8400 tons. This is conveyed by a wire ropeway 2·9 miles long to a railway station at Ilderhausen belonging to the mine. This railway connection and the ropeway together cost about £12,500.

The Bückeberg Collieries.—At the Obernkirchener Gesammtstein-kohlenbergwerk, on the Bückeberg in Hanover, the occurrence of coal is closely related to that of the Deister,* but as regards the quality of the fuel it forms a link between the Deister coal and that of the Weser and Wichen ranges. At Bohmte, four seams of anthracite, varying up to nearly 2 feet in thickness, have been worked, the anthracite containing about 91·5 per cent. of carbon, and being very free from ash. Of three other seams occurring on the right bank of the Weser, the lowest, some 18 inches thick, consists of anthracite. The seam worked at the Bückeberg averages about 16 inches in thickness, increasing in places to a thickness of more than a yard, while just as frequently it thins almost to a mere parting. The configuration of the seam corresponds exactly with that of the surface of the hill in which it occurs, even the valleys and watercourses being represented. This, it is pointed out, is geologically strongly opposed to the generally accepted erosion theory of surface forms. Mining appears to have been carried on here for some five hundred years. The fire-damp found here smells strongly of petroleum, and contains, in addition to methane, up to as much as 38 per cent. of ethane. The workpeople employed number 1620, and the annual output amounts to 240,000 tons, or 0·5 ton per man (total) per shift, or 0·7 ton per shift for every man employed under ground. A coal-washing plant is erected at the mine, and the washed coal goes to a coke-oven plant, where 20,000 tons of good strong coke are made annually in thirty-two Schaumburg ovens, and 5000 tons of the light swollen coke "so much liked in copper smelting" in Smet ovens.

The Brown-Coal Deposits of Bavaria.—C. W. von Gümbel† gives a geological description of the occurrence of brown coal in Bavaria, and appends statistics of the production of the collieries at Peissenberg, Pensberg, and Miesbach. The output of the brown-coal mines of Upper Bavaria amounted in 1894 to 497,576 tons.

A New Spanish Coalfield.—F. Laur ‡ gives detailed particulars of a new coal basin in Old Castille in the north of Spain. This basin

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 647.
† *Zeitschrift für praktische Geologie*, 1896, pp. 114–115.
‡ *L'Echo des Mines*, vol. xxii. pp. 65–66, 97–104.

had certainly not escaped the notice of geologists, but owing to the absence of any railway, and to its being situated at the foot of the Cantabrian Mountains in a country formerly somewhat difficult of access, it had not come under general notice. But it was evident that this basin, situated nearer to the great central markets than that of the Asturias, would rank with those of the greatest importance did it but possess the advantage of railway communication. There are more than forty seams. Some of them are of great thickness, one of them being 19·68 yards. In short, there is a coal formation more than 68¾ miles in length without counting the small basin at Baruelo.

Coal in Portugal.—R. Fisher * states that very little has been done in Portugal in connection with coal mining, although there are three productive districts. In the north, near Oporto, anthracite of good quality occurs, but is often mixed with shale. Here there are four principal mines. Semi-bituminous coal exists near Busaco at Santa Catherina, but is not worked. Near Batalha there is a coalfield of 12,000 acres with several outcrops of coal approaching lignite in quality. The output is small and the coal poor. Six miles south, at Porto de Moz, there is a 3-foot seam. Sections of several of the seams mentioned are given. The imports of coal for 1892 and 1893 are given as 603,696 and 408,558 tons, and of coke 10,628 and 8218 tons. Import duties of 3s. 6d. per ton are levied, but have not done much in advancing the native industry.

Coal in Assam.—G. Turner † states that although the existence of coal in Assam has been known since 1825 it was not worked on a large scale until 1882. The concession to the Assam Railway and Trading Company covers about thirty square miles, and coal has been proved in the Patkai Naja hills throughout this area, and also to the east and west. The seams have a high dip towards the hills of one in two or three. There are now four separate collieries, of which one is being developed, all on one seam, which is as much as 50 feet and more in thickness, with two partings of shale. These increase in number and thickness in places so as to divide the coal into several seams. With thin partings the seam is worked as a whole, but when they increase to 7 or 9 feet the upper and lower portions only are won. A method

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* *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 121–126.

† *Ibid.*, vol. x. pp. 356–364, with one plate.

similar to that used in South Staffordshire is employed with sides of work 120 to 140 feet square. The coal is fairly hard and compact, but it is very brittle, and disintegrates on exposure. It is very liable to spontaneous combustion. By keeping the workings above water level the water is readily disposed of. The natives will not work, so imported coolies are employed at wages ranging from five rupees per month for boys up to eighteen rupees for engine-drivers, but they also receive a certain amount in board, &c. Wood and iron tubs, 22-lb. rails, and haulage by main and tail rope or ponies are employed. Mine timber is obtained in the locality, but is not durable. Petroleum is often found on the surface but never in the coal seams, and fire-damp has only a restricted occurrence. An analysis of the coal is as follows:—

Carbon.	Hydrogen.	Oxygen and Nitrogen.	Sulphur.	Ash.	Moisture.
75·700	6·047	13·107	1·390	1·120	2·636

It is highly bituminous, soft, and cakes freely. Most of it is produced in the form of rough slack, but it gives excellent results if the fire-bars are placed close together. In 1894 the amount produced was 169,335 tons. It is conveyed by rail, and then down the river even as far as Calcutta. A number of sections of the seam are given.

The Giridih Coalfield in Bengal.—The old view of igneous rocks as merely accidental and irregular intruders into the regular sedimentary series has been greatly modified by the results of petrological researches, and now it has been found possible by T. H. Holland and W. Saise,[*] from an investigation of rock structures, to obtain a complete account of a series of events in a district in the Giridih coalfield in Bengal. They show how a liquid rock-magma of highly basic composition was injected as a series of dykes through the rocks of this area, at a temperature so high that near the dykes the coal was coked, and columnar structure developed in it, while sandstones were so far fused that they came to closely resemble siliceous lavas. This magma was rich in chlorine, as the abundance of apatite in it shows, and from it thermal waters conveyed chlorides in solution to permeate the rocks around.

Coal in Newfoundland.—In his letters and reports from 1763 to 1767 Cook specially mentions the coal that he discovered in his exploration of the rivers and lakes of the west coast. At the time he was treated as a visionary, but after the lapse of nearly a century and a half all Cook's views are proved to be correct. The coal for which he was

[*] *Records of the Geological Survey of India*, vol. xxviii. pp. 121–138.

derided is, according to D. W. Prowse,* now being worked, and some truck-loads will shortly be sent by railway to St. Johns. The most important coal area close to the railway at the head of the Grand Lake has been thoroughly explored during the summer of 1895 by J. P. Howley, the head of the Geological Survey of Newfoundland, and several workable coal seams have been discovered over an area of 50 square miles. The discovery has revolutionised the whole state of affairs in Newfoundland.

The island is also rich in iron ore. A deposit at Belle Isle, about 12 miles from St. Johns, is now being worked by a Nova Scotia syndicate. It yields 60 per cent. of iron. A larger deposit occurs near St. George's Bay.

Coal in Georgia.—At the Atlanta Exposition several samples of coal from mines in the State of Georgia were shown. At Chickamanga there is a 4¾-feet seam with a 9-inch parting, from which 200 to 300 tons are produced daily. In the vicinity of Coal city there is a seam 9 feet thick, of which 4 feet is worked on a considerable scale.†

Stratigraphy of the Kansas Coal Measures.— The eastern quarter of Kansas is covered with coal-measure rocks, resting directly upon the Mississipian formation. The geological features of the coal measures have been carefully studied by E. Haworth.‡ From his results it may safely be concluded that the coal-measure strata are in a general way conformable with the upper surface of the Mississipian floor. The different formations lie one above the other in regular order, similar to that found to obtain in other parts of the world. The general character of the shales throughout the coal measures is such that they must have been deposited, in the main, in shallow water, probably ocean water. The thickness of the coal measures cannot be much less than 2500 feet.

The Eastern Coal Regions of Kentucky.—According to G. Macfarlane,§ the eastern coalfield of Kentucky covers about 11,000 square miles in all. On the east and south it extends to the State lines of West Virginia, Virginia, and Tennessee. Its western boundary may be roughly described as an irregular line beginning at the Ohio River in Greenup County, thence through the counties of Carter,

* *The Times*, November 26, 1895.

† *Engineering and Mining Journal*, vol. lx. p. 297.

‡ *American Journal of Science*, vol. l. pp. 452–466.

§ *Transactions of the American Institute of Mining Engineers* (Atlanta Meeting).

Memfee, Wolfe, Esthill, Jackson, Rockcastle, Pulaski, and Wayne, to the Tennessee line.

The changes in the rock intervals and in the coal seams from the north-eastern end of the field to the south and south-western end are so great that no identification of the coals has yet been made, and the correlation of the Kentucky coals with those of other States in the Appalachian coalfield is likewise involved in a conflict of opinion. The longer the matter is studied the more confusing it becomes. The first examination of this field leads to much more satisfactory conclusions than can be accepted after more thorough investigation; and the identification of the various coal seams, supposed to be established forty years ago, is now doubtful. The author also describes the various mining operations, with some information as to the territory adjacent to, or tributary to, developed sections, using generally local or Kentucky nomenclature; and also some observations on the stratigraphy and correlation of the coal seams, which may be useful in stimulating study by geologists.

Coal in Texas.—Up to the present time coal-mining has not been extensively carried on in Texas, but there are two collieries turning out 300 and 1800 tons daily. The Bowie mines work a square mile by a shaft 419 feet in depth and 18 by 7 feet in area, divided into three compartments. The seam is about 4 feet thick, with a sandstone roof and fireclay floor. An assay of the coal shows:—

Fixed Carbon.	Volatile Matter.	Ash.	Sulphur.	Water.
47·22	28·00	14·04	1·74	9·00

A short description of the plant is given, and an illustration of the surface works showing a rather peculiar headgear.*

West Virginia Coals.—J. W. Paul † gives the analysis, calorific values, and comparative efficiency of seventeen samples of coal from West Virginia, together with other particulars as to their source of origin and nature of the coal and ash. Exeept two, all the coals examined are bituminous, and the water evaporated from and at 212° F., according to the calorimeter, varies from 12·75 to 15·496 lbs. per lb. of coal. The commercial efficiency is given as 7·78 to 9·38 lbs. The percentage of ash ranges from 1·30 to 8·50. Some of these results are questioned by W. Kent,‡ and further particulars are given in reply by the author.§

* *Engineering and Mining Journal,* vol. lx. p. 443.
† *Ibid.,* vol. lxi. pp. 233–234.　　　‡ *Ibid.,* p. 275.
§ *Ibid.,* p. 349.

The Coalfields of South Brazil.—R. Zeiller [*] observes that the question of the geological age of many of the smaller coal basins of South Brazil has given rise to considerable discussion. Carruthers thought they were Carboniferous, while Koken maintained that they were Triassic. The author has himself investigated the matter, and has arrived at the conclusion that in the Arroyo basin the examples of our Carboniferous flora are found in conjunction with examples of the Glossopteris flora from the Austral-African and Austral-Indian districts. Southern Brazil would thus form the boundary between these two vast botanical provinces, into which the vegetation of the earth was so long divided. The age of these Brazilian coal basins may thus be placed at about from the end of the Carboniferous to the beginning of the Permian.

Coal in Colombia.—The coal deposits in Colombia, so far as is known, are of considerable extent. Coal is found all along the east coast of the Gulf of Uraba and in the vicinity. In Antioquia there are as many as thirty-four seams, some of them 10 to 12 feet in thickness. Anthracite, bituminous coal, and lignite are found close together. At the Zancudo mine in Antioquia fifteen seams are worked, and 50,000 tons are produced yearly. Some of the coal will not coke, other varieties give 45 per cent. in heaps. C. F. Z. Caracristi has stated that his explorations show that the coalfields extend over ten thousand square miles, and that a considerable amount of petroleum is found in the Gulf of Uraba.[†]

Coal in the Argentine Republic.—G. Bodenbender [‡] has published the results of his investigation of the occurrence of coal in the province of Mendoza, from which we extract the following details.

In the vicinity of the railway station at Retamito, between Mendoza and San Juan, coal of Lower Carboniferous age has been proved to exist. Twenty miles east of Retamito a seam of bituminous shale and impure bituminous coal has been discovered. The seam is 20 to 24 inches thick, courses from north to south, and dips 25° to the east. Although not workable, the coal is of scientific interest as affording clear evidence of the occurrence of coal, and it is not impossible that in the Sierra, between Mendoza and San Juan, workable seams will be discovered by boring.

[*] *Glückauf,* vol. xxxii. p. 33.
[†] *Engineering and Mining Journal,* vol. lx. p. 609.
[‡] *Boletino de la Academia Nacional de Cordoba,* vol. xiii. ; *Zeitschrift für praktische Geologie,* 1896, pp. 31-32.

Coal also occurs near Cacheuta, to the south of Mendoza, where two collieries are in operation. The seam occurs in grey sandstone, and has a thickness of 24 inches and a dip of 30° to 35° west. The coal is, however, very impure.

Not less interesting is the occurrence of coal in the Sierra Malargue, long. 70°, lat. 35° 35', in cretaceous marls. This coal appears to be a product of the alteration of asphalt. A similar deposit is met with at La Manga in cretaceous strata.

In a subsequent paper the author * gives the result of an exhaustive study of the geological age of the coal deposits of the Argentine Republic.

Relative Value of Coals.—H. M. Chance † gives some useful hints to consumers. The composition of the coal, as shown by analysis, is the best criterion, care being always taken that the analyses represent properly selected average samples. The following are given as the typical compositions of high and low grade anthracite, semi-bituminous and bituminous coal :—

High-Grade Coals.

						Anthracite.	Semi-bituminous.	Bituminous
Water	.	.	.	.	.	1·00	1·00	1·00
Volatile matter	.	.	.	.	5·00	18·00	40·00
Fixed carbon	.	.	.	.	.	88·50	75·50	53·50
Sulphur	.	.	.	.	.	0·50	0·50	0·50
Ash	.	.	.	.	.	5·00	5·00	5·00
		Totals	.	.		100·00	100·00	100·00

Low-Grade Coals.

						Anthracite.	Semi-bituminous.	Bituminous.
Water	.	.	.	.	.	2·00	3·00	4·00
Volatile matter	.	.	.	.	5·00	15·00	34·00
Fixed carbon	.	.	.	.	.	75·00	67·00	46·50
Sulphur	.	.	.	.	.	2·00	3·00	3·50
Ash	.	.	.	.	.	16·00	12·00	12·00
		Totals	.	.		100·00	100·00	100·00

* *Revista del museo de La Plata*, vol. vii. p. 129 ; *Zeitschrift für praktische Geologie*, 1896, pp. 120–121.

† *Engineering Magazine*, vol. xi. pp. 40–46.

Nitrogen in Coal.—J. Landin * observes that the percentage of nitrogen in coal is somewhat small, varying in Westphalian and English coal between 1·3 and 1·6 per cent. On dry distillation only a small part of the nitrogen passes into ammonia or cyanogen. In the case of the Ruhr coal this amounts to from 0·2 to 0·25 per cent. of the weight of the coal. A further small portion of the nitrogen passes into the tar, but the major portion is to be sought for in the coke and in the gas. The quantity of nitrogen that is converted into ammonia is in no way proportionate to the total percentage in the coal. Saar coal, with 1·176 per cent. of nitrogen, gave 0·1874 per cent as ammonia, and others with 1·555 and 1·479 per cent. yielded 0·1850 and 0·2086 per cent. Changes in the method of distillation also change the yield. The addition of lime to the coal, or the action of steam, increases the quantity of ammonia produced. Sixty experiments, with fifteen different varieties of coal, gave from 4·2 to 63·7 lbs. of ammonium sulphate per ton of coal. The lowest quantity was derived from Australian and the highest from Italian lignite. The mode of distribution of the nitrogen is, according to Knublauch, the following :—

	Ruhr Coal. I.	Ruhr Coal. II.	Saar Coal.
	Per Cent.	Per Cent.	Per Cent.
Coke	30·0	35·6	63·9
Gas	55·0	47·1	16·1
Ammonia	11·9	14·1	15·9
Cyanogen	1·8	1·8	} 4·1
Tar	1·3	1·4	

In the purifying boxes cyanogen is absorbed as well as sulphuretted hydrogen, ferrocyanide being formed, and occasionally ammonium sulphocyanide. The cyanogen may, that is, combine with iron or sulphur in this purification process, ammonia being the greatest enemy to the formation of ferrocyanide. In the treatment of Westphalian coke, about 50 per cent. of the nitrogen remains in the coke, 30 per cent. passes into the gas as a deleterious ingredient, diminishing the luminosity, 12 to 14 per cent. forms ammonia, not quite 2 per cent. hydrocyanic acid, 1·33 per cent. exists as nitrogen compounds in the tar, and at the most 0·2 to 0·25 per cent. of the nitrogen passes into valueless products. The rational utilisation of the valuable nitrogen products is therefore of great importance.

* *Teknisk Tidskrift*, vol. xxvi. pp. 24–27.

Vanadium and Platinum in Coal.—It is stated * that further deposits of vanadium-bearing coal have been discovered. The locality is not divulged, but it is believed to be near that previously described as occurring in the province of Mendoza, Argentina, near the frontier of Chili. The coal contains partings of earthy matter. A ton of the coal, when burnt, left 15 per cent. of residue, and gave 2·9 per cent. of metallic vanadium and 0·23 per cent. of platinum metals, chiefly platinum. These percentages appear to relate to the coal, and not to the ash.

The Composition of Coal Ash.—E. Prost † gives the results of an investigation of the fusibility and composition of the ash of twenty-three specimens of Belgian coal. The ashes examined after fusion consist of various silicates, composed essentially of silicate of alumina, and, subordinately, of silicates of iron, lime, magnesia, and alkaline silicates. The degree of fusibility depends especially on the relation existing between the alumina and the silica, on the one hand, and between the other bases and the alumina on the other hand. It diminishes when the amount of alumina increases, the bases diminishing, and inversely it increases when with the same quantity of silica the bases increase in proportion to the alumina, at least up to a certain limit. The least fusible ashes are those in which the amount of alumina reaches from 32 to 34 per cent., and the amount of silica from 46 to 50 per cent. The increase of fusibility increases more rapidly with the diminution of alumina than with the increase of other bases, the percentage of silica remaining the same. Oxide of iron has a greater influence than lime on the degree of fusibility. The maximum degree of fusibility is when the molecular proportions are :—

Silica, 100 ; oxide of iron, 11·3 ; alumina, 28·5 ; lime, 6·8 ; magnesia, 8·9.

The fusibility is not affected by oxide of iron, lime, and magnesia beyond a certain limit. When the proportions are too considerable, these bases, infusible themselves, act in the same manner as an increased amount of alumina would—that is to say, they diminish the fusibility of the ash.

* *Engineering and Mining Journal,* vol. lxi. p. 81.
† *Revue Universelle des Mines,* vol. xxxi. pp. 87–98.

III.—*CHARCOAL.*

Charcoal Kilns.—Illustrations have appeared * of a charcoal-making plant erected in conjunction with a new charcoal blast-furnace at Gladstone, on Lake Michigan. The battery consists of forty 65-cord kilns requiring 120 cords of wood daily. The kilns are 31 feet in external diameter at the base, and 27 feet at the skewback, which is at a height of 14 feet. A gas flue 2000 feet in length takes the gases to the chemical works, where they are condensed. Tar and alcohol are produced, and it is also intended to erect plant for the production of acetate of lime and acetic acid.

IV.—*COKE.*

Improvements in the Manufacture of Coke.—L. Rürup † refers to a number of improvements which have of late been introduced into the manufacture of coke. He mentions an improvement in beehive ovens by A. Dickinson, who employs a perforated and divided false roof for the purpose of a better distribution of the air entering the oven. One section of this false roof connects with an intake, and the other with the stack. E. Peitz endeavours to obtain a better circulation of the gases in the oven walls by connecting the horizontal channels with each other, so arranging these connections that the openings taper off in width in such a way that a wide opening is between one pair of channels and a narrow opening between the next superimposed pair. J. Margirius keeps all sources of entry of gas completely distinct, with a view to obtain a perfectly regular heating of the bottom and sides of the oven. The products of combustion do not mix until the gases, which pass for a certain distance into the channels in the walls, have been completely burnt. F. J. Collin has introduced the following modification into horizontal ovens : The coking-chambers have in their separating walls many parallel flues which are completely separate, the products of combustion only meeting in the channels below the oven wall.

Messrs. Otto & Co. have modified their horizontal ovens in a way the author describes by means of an illustration, the hot-air channels connecting by openings with the gas channels in such a way that the wall

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* *Iron Trade Review*, vol. xxix. No. I. pp. 34–36.
  , † *Chemiker Zeitung*, vol. xx. pp. 201–202, with five illustrations.

between each pair of chambers enables each chamber to be separately heated. By the arrangement of double channels, each oven chamber can be separately charged and emptied without the adjoining chamber being cooled down. H. Salle has adopted a modified form by which each wall of an oven can be separately heated independently of that of the neighbouring oven, while in the types of furnaces arranged for the collection of the by-products which have hitherto been in use, the combustion chamber proper is cooled by the abstraction of heat by the air for the combustion, which preheats itself at the walls of the oven channels. This difficulty is avoided by a modification suggested by E. Festner and G. Hoffmann. These preheat the air by the aid of the escaping gases. The gases returning from the condensing plant are returned to the ovens and burnt in the combustion channels. The air and gas channels are so arranged above one another that the top and the bottom of an air channel are formed by two gas channels, or by the combustion chamber and a gas channel.

Guido Paar has patented an oven for the simultaneous manufacture of coke and lime. This the author illustrates. Around the side of the lime-kiln a kind of series of Appolt coking chambers are arranged in such a way that they act as gas-producers, the gases formed in the coking passing through orifices in the side of the kiln into the kiln itself. Various possible modifications of this arrangement are mentioned. H. Borgs deals with the temperature attained near the oven doors. He raises the coal to the necessary coking temperature by placing between the coal and the door during the coking process an empty space. The door he uses consists of two parts, an outer, and an inner one connected with it by screws. Before charging the oven the door is closed, and the inner portion screwed forward a definite distance into the oven. When after some hours the coal has caked together, the inner portion of the double door is screwed back again towards the outer door, and in this way an empty space is produced between the coal undergoing coking and the furnace-door, thus causing the coal to be adequately exposed to heat in all directions. The author discusses the various proposals, and he considers this one of Borgs' to be both simple and practical.

The Coking Power of Coal.—L. Campredon,* in order to obtain some measure of the coking power of different coals, mixes the powdered sample with a sufficient weight of an inert body, such as sand, so that it will on coking produce a coherent mass. In practice he uses 1 gramme

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* *Comptes rendus de l'Académie des Sciences,* vol. cxxi. pp. 820-822.

of coal, powdered to pass through a sieve of 400 meshes to the square centimetre (about 2600 meshes per square inch), and mixes it with sand which passes through a 100 mesh sieve, but remains on a 400 mesh. The mixture is coked in porcelain crucibles at a red heat, and after a few trials the maximum weight of sand is readily determined. The binding power ranges up to seventeen times its weight of sand for the most binding coal, and to twenty for pitch. This method has been tried for the last three years at the laboratory of the Vignac Works, and below are given a few results obtained with coals dried at 100° C.

No.		Volatile Matters.	Ash.	Fixed Carbon.	Binding Power.
		Per Cent.	Per Cent.	Per Cent.	
1. {	Coal from Aberdare, Merthyr (South Wales) . . . . }	10·90	6·20	82·90	0
2.	Coal from Newcastle	34·25	10·80	54·93	2
3.	Coal from Scotland	34·72	8·35	56·93	4
4.	Small coking coal from Cardiff . .	19·80	7·70	72·50	6
5.	Coal from Lens (Pas de Calais) . .	27·20	8·70	64·10	13
5B. {	No. 5 oxidised by heating at 100° during one year . . . . }	28·12	8·55	63·33	0
6.	Small coking coal from Newcastle .	27·83	8·75	63·42	14
7.	Small coking coal from Newcastle .	29·50	8·50	62·00	17
8.	Coal-tar from Beckton (London) . .	44·82	0·60	54·58	20

Coke-Ovens.—A. L. Steavenson * offers a defence of the beehive oven against other types, showing that the former gives coke of good quality and free from moisture when quenched inside the oven. The waste gases from these ovens are used for raising steam, whilst the price of retort-oven by-products is steadily diminishing.

A detailed description has been published † of the new coke-making plant at the Randolph Colliery near Bishop Auckland, where there are sixty ovens of the Coppée type.

J. A. Montgomery ‡ gives some calculations to show the enormous amount of by-products lost owing to the use of beehive ovens. He estimates that the existing ovens cost about 14,000,000 dollars, and that to replace them would cost 45,000,000 dollars. As a set-off to this the waste in 1892 is given as 24,000,000 dollars.

According to R. M. Atwater,§ it is estimated that the available coal in

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* *American Manufacturer*, vol. lviii. p. 300.
† *Colliery Guardian*, vol. lxxi. p. 401.
‡ *Proceedings of the Alabama Industrial and Scientific Society*, vol. v. pp. 10–19.
§ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xii. pp. 73–86.

the Connellsville district will produce 70,000,000 tons of coke. At the 1895 rate of consumption this will last about twelve years, and the existing beehive ovens will wear out at or before that time. Retort ovens can thus take their place in other fields without any sacrifice. The author then proceeds to show that the retort oven produces denser coke owing to the greater depth, some 6 feet instead of 2 feet, and owing also to the impossibility of expansion as in the beehive oven. There is also a gain in the retort owing to the partial decomposition of volatile hydrocarbons, and the impurities being spread over a larger mass are diminished in regard to their percentage. The objections to the regenerator, as applied to coke-ovens, are considered, and the methods of recuperation as used in the Semet-Solvay oven are to be preferred, as the heating effect is more uniform.

The Semet-Solvay Oven.—R. M. Atwater [*] classifies retort ovens under two headings according as they have vertical or horizontal flues. Vertical flue ovens are either without regeneration, as in the Coppée type, or with, as in the Otto-Hoffmann oven. Horizontal flue ovens have thick brick walls, as in the Carvés type, or thin tile ones, as in the Semet-Solvay oven. The latter is preferred, as the long course for the gas and the thinness of the walls causes the heat to be better utilised. The author quotes at some length from the report of a test made by J. Fulton at Lorraine, Ohio, with Connellsville coal coked in Semet-Solvay ovens and in beehive ovens.   Over two thousand tons of coal were used, and it was determined that 20-hour retort coke was about equal in hardness to 72-hour beehive coke.   By leaving the coke longer in the retort ovens a better product was obtained; probably 23 or 24 hours would be sufficient. The coke made was used in a blast-furnace, which for five days was run on beehive coke and then five days on the retort coke with the following results :—

	Beehive Coke Test.	Semet-Solvay Coke Test.
Iron ore used, lbs. . . .	4,260,080	4,711,190
Limestone used, lbs. . .	729,400	870,700
Coke used, lbs. . . .	2,403,060	2,775,613
Pig iron made, tons . . .	1,122	1,205
Coke, per lb. of iron, lb. . .	0·956	1·028
Coal, per lb. of iron, lb. . .	1·421	1·389

* Paper read before the Ohio Institute of Mining Engineers, January 1896, through the *Iron Trade Review*, vol. xxix. No. 5, pp. 14-16.

The latter figures are obtained by allowing for the moisture and ash in the two cokes. The advantages of retort ovens for the west central district of the United States are then considered, and the utilisation of by-products is discussed.

A battery of twelve of these ovens has been in use for some time at Syracuse, New York, and their work compares as follows with that of beehive ovens :—

	Semet-Solvay Oven.	Beehive Oven.
Number of ovens	12	12
Coking period, week's average, hours . . .	20	51·50
Ovens emptied in 24 hours	14·40	5·50
Coal used in 24 hours, tons	71·67	27·76
Coke produced in 24 hours, tons	57·97	17·30
Ammonium sulphate produced in 24 hours, ton .	0·77	...
Tar produced in 24 hours, tons	2·65	...
Yield of coke per cent.	80·70	62·30
Yield of ammonium sulphate per cent. . . .	1·075	...
Yield of tar per cent.	3·69	...
Value of coke made in 24 hours, shillings . . .	402·70	120·08
Value of ammonium sulphate made in 24 hrs., shillings	214·58	...
Value of tar made in 24 hours, shillings . . .	122·72	...

The total value of the products produced from the Semet-Solvay ovens thus amounts to £36 as compared with £6 in the case of the beehive ovens.[*] The products obtained from one ton of coal were of the value of 10·52 shillings in the case of the modern ovens as compared with 4·19 in that of the older ones. A Semet-Solvay oven costs £315, a beehive £63, the former lasting ten years and the latter five.

Recovery of By-Products in the Jameson Oven.—J. Jameson,[†] although his own oven eventually proved to be a failure, believes that this method of recovery of by-products in open ovens, unless displaced by some more effectual one, will certainly in the course of time come into extensive use. Some fourteen years ago his first experiments were made at the Felling chemical works, and the results were so satisfactory that many ovens were altered throughout the country. In all cases the results were at first equally good, but it was soon found that the gas drawn off became at first explosive and then non-combustible. Of course under these conditions the yield of by-products fell off. Ulti-

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[*] *Stahl und Eisen*, vol. xv. p. 1070.

[†] *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 330–336.

mately this was ascribed to the leakage of air into the bottoms. When they were new they behaved properly, but after continued use the air found access; and although experiments were conducted to find an impervious bottom, they were suspended before it could be decided whether the costs of renewals would exceed the saving in the by-products. One bottom was indeed made that lasted for a year, and this consisted of a water-cooled iron pan. If this had been adopted in the first instance, the author thinks that the results would have been very different.

Coke for the Foundry.—T. D. West * gives some notes on coke for foundry purposes, and states that oven coke was first made in America by two carpenters and a stone-mason in Pennsylvania in 1841. Their experiment was not financially successful, and until 1885, according to J. B. Laux, but few ovens were built. About twelve years ago anthracite was chiefly used in foundry work, but now coke has almost entirely replaced coal. The beehive oven is illustrated, and other types such as the retort ovens are briefly referred to, and then the author turns his attention to the composition. The effect of sulphur is of course pernicious. Coking reduces the amount in the coal, and pure water is necessary to quench it. The composition of the iron melted has a considerable influence on the effect of the sulphur. The ash in foundry coke generally ranges from 10 to 14 per cent. An analysis of ash from Connellsville coke shows—

SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	P_2O_5.	$K_2O + Na_2O$.
5·413	3·262	0·479	0·243	0·007	0·012	traces

The density and hardness of coke are then discussed. The former property depends on its porosity. A silvery bright coke is preferred by the author, although he admits that black ends do not seem to be unsuitable for use. A 72-hour coke is generally of more value than a 42-hour coke, and this is not solely due to the greater time that it has remained in the oven, but also to the fact that greater care is taken in manufacturing and subsequently handling it. Washing the coal is then referred to, and then attention is given to charging the ovens. As a rule, the coke is now watered in the ovens before drawing, as less moisture is retained. It is also evidently advantageous to store coke under cover, although it has been said that weathering reduces sulphur. Care has to be taken in drawing the coke to reduce the amount of smalls, and the quality may

* *Iron Trade Review*, vol. xxix. No. 7, p. 15; No. 8, p. 8; No. 10, p. 14, with numerous illustrations.

be improved by picking out black ends and badly burned lumps. In the United States the beehive oven is usually employed, and this the author describes and illustrates; but he also pays some attention to the heap method of burning, in which the yield is from 50 to 55 per cent. as compared with 60 to 70 per cent. from ovens. The following table by J. Fulton for Connellsville coke is quoted :—

Hours in Oven.	Coal Charged.	Ash Made.	Fine Coke Made.	Market Coke Made.	Total Coke Made.	Per Cent. Yield.				Per Cent. Loss.
						Ash.	Fine Coke.	Market Coke.	Total Coke.	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.					
67	12,420	99	385	7,518	7,903	0·80	3·10	60·53	63·63	35·57
68	11,090	90	359	6,580	6,939	0·81	3·24	59·33	62·57	36·62
45	9,120	77	272	5,418	5,690	0·84	2·98	59·41	62·39	36·77
45	9,020	74	349	5,334	5,683	0·82	3·87	59·13	63·00	36·18
...	41,650	340	1,365	24,850	26,215	0·82	3·28	59·66	62·94	36·24

The author does not pay much regard to the analysis, but rather trusts the reputation of the coke and to personal experience in its use.

V.—LIQUID FUEL.

Genesis of Petroleum.—C. Ochsenius [*] discusses the genesis of petroleum and controverts the theories propounded by C. Engler.

The Flashing-Point of Petroleum.—C. A. Lobry de Bruyn [†] observes that at the International Fire Brigade Congress, held in September 1895 at Amsterdam, the wish was generally expressed that the flashing-point of petroleum might in future be raised to the 40° C. Abel test. The author quotes the present official requirements in the different countries, and shows that they are mostly below this, and occasionally greatly so. He then proceeds to show the number of fires in different large towns in Europe and the United States, and the large percentage of these which were shown to be due to the use of petroleum. He then sketches in outline the past history of the question of the permissible flashing-point for petroleum. Petroleums are more or less dangerous according to the percentage of readily volatile constituents they contain.

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[*] *Zeitschrift für praktische Geologie*, 1896, pp. 65–68.
[†] *Chemiker Zeitung*, vol. xx. pp. 251–265.

He then discusses the question of the composition of the petroleum con-
sumed, and the results obtained when it is submitted to fractional distil-
lation.   Other points he discusses are the degree of danger connected
with its use and the question of the flashing-point in the United King-
dom and in Germany.   This he deals with at much length.   Other
matters referred to are the degree of illuminating power and the price of
the oil, and he quotes Davis' statement that "the raising of the flashing-
point is not equivalent to raising its price," and similar statements by
Powell and Young.   Finally, he deals with the question of the exhaustion
of the United States deposits, and then sums up the question of the
flashing-point by a series of deductions which include the following:—
(1) That the number of accidents shown to have been due to the use of
petroleum urgently calls for State interference; (2) that by increasing
the legally required flashing-test to at least the 40° C. Abel test, this
danger is almost completely avoided; (3) the flashing-tests at present in
use in most European countries are too low, and do not afford the protec-
tion demanded.

R. Nelson Boyd * discusses the value of petroleum as a fuel.

Sulphur in Petroleum.—C. Engler † observes that while Baku
petroleum is an excellent illuminant, it requires to be burnt in special
kinds of lamps, those commonly employed for American petroleum not
affording an adequate air supply when the heavier Russian oil is used.
The Ohio oil district is a most important one, though there are still grave
objections made to this oil, the assumption being that its sulphur con-
tents is too high.   The raw oil, it is true, does contain large quan-
tities, but the use of the Frash process in refining eliminates a very
large portion.   This process consists in treating the oil with roasted
copper ore.

Of the various methods which have been suggested for the determina-
tion of sulphur in petroleum, none of those with which the author is
acquainted proved completely satisfactory, Heusler's being, however, the
best.   The author prefers to burn the oil and to pass the products of
combustion through a solution of bromine in caustic potash, or potas-
sium carbonate, precipitating and weighing as barium sulphate.   He
describes and illustrates the apparatus he employs, and gives a number
of results of determinations of sulphur in various kinds of petroleum
of commerce.   These vary from 0·0195 per cent. up to 0·2098 per

* *Colliery Guardian*, vol. lxx. p. 748.
† *Chemiker Zeitung*, vol. xx. pp. 197-199.

cent., the latter appearing to be abnormal. The results stated are as follows :—

Petroleum.		Sulphur. Per Cent.
Astral	. . . .	0·0195
Ohio	. . . .	0·0244
Lima (Ohio)	. . . .	0·0432
Standard Oil Company	. . . . . .	0·0211
Standard Oil Company	. . . . . .	0·0362
Standard White (Pennsylvania)	. . . .	0·0307
Other United States Oils	. . . . . .	$\left\{ \begin{array}{c} 0·04825 \\ \text{to} \\ 0·0509 \end{array} \right.$
Russian (Baku)	. . . .	0·0262
Russian (Baku)	. . . .	0·0276
Austro-Galician	. . . .	$\left\{ \begin{array}{c} 0·0406 \\ \text{to} \\ 0·0615 \end{array} \right.$
Alsatian	. . . .	0·0661
Alsatian	. . . .	0·0684

The Lima oil, it will be seen, stands about midway on the list, containing a little more sulphur than refined Pennsylvania oil, but less than that in the oil obtained from Alsace. The prejudice which exists to its use as a luminant in Germany is therefore unfounded.

The question of the determination of sulphur in petroleum is also considered by R. Kissling,[*] who describes the apparatus he employs, and gives a number of results which vary for Lima oil from 0·01032 to 0·02208 per cent., for Pennsylvania oil from 0·01285 to 0·01347, and for other oils from 0·00928 to 0·02481. The author's method is similar to that of Heusler. The oil is burnt, and the products passed into a concentrated solution of potassium permanganate, the sulphur being weighed as barium sulphate.

The Oil Deposits at Oelheim.—The Oelheim district is described geologically,[†] and the total quantity of oil that has been raised there up to the end of 1894 is stated to have amounted approximately to 26,560 tons, the quantity raised in 1894 being only some 400 tons, as compared with about 1500 tons in 1885. The gradual falling away of the oil industry in this district is attributed rather to commercial reasons than to lack of oil.

Petroleum in Alsace.—L. van Werveke [‡] describes the recent investigations regarding the occurrence of petroleum in Alsace. The

[*] *Chemiker Zeitung,* vol. xx. p. 199.
[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliii. pp. 676–678.
[‡] *Zeitschrift für praktische Geologie,* 1896, pp. 41–45.

annual output of crude oil has increased from 1805 tons in 1879 to 12,265 tons in 1894. The total production from 1879 to 1894 inclusive was 98,160 tons. Of the boreholes put down, 220 yielded traces of oil, 28 yielded 1 to 10 barrels of 150 kilogrammes in twenty-four hours, 24 yielded 10 to 100 barrels, 4 yielded 100 to 200 barrels, 1 yielded 200 to 400 barrels, and 2 yielded 400 to 500 barrels.

Petroleum of the Credo.—According to Boulangier,* a deposit has recently been discovered at the Credo, on the Franco-Swiss frontier, composed of beds of sand impregnated with petroleum rich in paraffin. It closely resembles the petroleum deposits of Pechelbronn in Alsace.

The Petroleum Industry at Baku.—B. H. Butler † gives a general account of the petroleum industry in the Baku district. In 1894, eight wells gave a production of over 120,000 barrels each, or more than a fifth of the total production. Nearly all the wells are furnished with 10 to 22 inch lining, and the cost of sinking up to 700 feet is given as about £4 per foot. Royalty amounts to 1·25 penny, and pumping costs 2·5 pence per barrel, and to give a profit the price should be 7·5 pence. The average daily production of the 46 wells completed in 1889 was 444 barrels, and the same wells gave only 66 barrels in 1894. The 81 wells finished in 1890 had an initial production of 284 barrels each, declining to 100 barrels in 1894. The average daily production of 87 wells drilled in 1894 amounted to no less than 1027 barrels. Most of the oil has to be pumped, as is shown by the following table, giving the production in barrels :—

	Flowing Wells.	Total Production.
1888	8,760,000	21,840,000
1889	5,040,000	23,040,000
1890	6,000,000	27,156,000
1891	4,680,000	32,952,000
1892	9,120,000	34,380,000
1893	13,080,000	38,964,000
1894	7,320,000	35,700,000
1895	13,000,000	45,100,000

In 1894, 220 wells were deepened, cleaned, or otherwise treated to bring them into work again. Of the wells finished in 1894, 5 were begun in

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* *Comptes Rendus de la Société de l'Industrie Minérale*, 1896, pp. 14–16.

† *Pittsburg Times*, through the *American Manufacturer*, vol. lviii. p. 374.

1890, 8 in 1891, 7 in 1892, and 29 in 1893. Of the open lakes and pools used as reservoirs for oil there are 111, with a capacity of 12,000,000 barrels. There are 16 covered earth cisterns, holding 5,000,000 barrels, besides which there are 49 covered and 82 open stone cisterns, holding 3,000,000 barrels. Iron tanks number less than 1000, and hold 3,286,000 barrels. There are about 150 refineries, where the aim is to get 30 per cent. of illuminating oil, 20 per cent. of lubricant, and 35 per cent. of mazoot, but the actual production is less.

The Russian petroleum industry is also discussed by G. T. Holloway.[*]

Petroleum from the Tscheleken Island.—K. W. Charitschkoff [†] states that the petroleum found on the island of Tscheleken, in the Caspian Sea, is a thick black liquid of 0·8686 specific gravity at 15° C., with a flashing-point of 51° C. It solidifies at 2°, as it contains above 5 per cent. of paraffin. The distillates show marked differences from the corresponding distillates of Baku petroleum, and approximate to those of Pennsylvania oil, as the following table shows :—

	Boiling Point, Deg. C.	Yield per Cent.	Specific Gravity at 15° C.
1.	Up to 200	2·8	0·7724
2.	200–250	11·9	0·7961
3.	250–270	7·6	0·8100
4.	270–310	6·6	0·3228

The yield of kerosene (petroleum) is consequently 28·9 per cent., or 22·3 per cent. if only the three first-named constituents are considered. Thirty per cent. of vaseline is obtainable from the thick oil above 0·90 specific gravity.

Petroleum in the Caucasus.—H. H. Niedenführ [‡] states that the petroleum-bearing zone in the Kuban Province in the Caucasus has a length of about 130 miles, extending from the Black Sea, at a point not far from the town of Anapa, and passing first in a northerly direction, touches the German colony of Michaelsfeld, and thence to the White River and on to Maikop. At many points petroleum shows at the surface, especially beyond the Kuban River, where mountain torrents disturb

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[*] *Engineering*, vol. lxi. p. 89.

[†] Paper read before the Russian Physical and Chemical Society, December 7/19, 1895; *Chemiker Zeitung*, vol. xx. p. 72.

[‡] *Chemiker Zeitung*, vol. xx. pp. 69–70.

the Tertiary beds. Despite the great extent of this oil-bearing region, in
only one spot has the industry been developed on an industrial scale.
This is in the Ilin district, four miles from the Ilinskaja station on
the Wladi-Caucasus Railway. The naphtha-bearing beds consist of soft
sandy clay deposits of the Lower Tertiary horizon and of ejection pro-
ducts of mud volcanoes. The distribution of the petroleum in these
is altogether irregular, and allows of no definite arrangement. The
naphtha itself is light green to white in colour, has a specific gravity of
from 0·755 to 0·815, and yields 80 per cent. of illuminating oil. Ac-
cording to Konschin's observations, this oil deposit may be considered
to be of a secondary character, being the product of a deeper lying oil
zone. In the Ilin district there were, in 1893, 100 wells. With a dip
of 45° the maximum borehole depth is 1400 feet. The uppermost oil-
bearing beds consist of very porous Tertiary dolomitic limestone. These
rest on a hard grey dolomitic limestone traversed by concretions and
seams of calcareous clay. Next follow clayey and sandy beds, and
then the deposits of the Lower Tertiary. The specific gravity of the
petroleum varies from 0·920 to 0·990, and the thickness of the oil-
bearing dolomite from 60 to 80 feet, relatively more oil being found in
its upper portions and more water in its lower parts. Here, too, the
occurrence of oil is secondary in character, the oil having been trans-
ferred into the dolomite bed by the action of subterraneous water.
The high specific gravity is due to the porosity of the rock having led
to increased evaporation. Below the dolomite oil zone are two others
which also carry oil. In both a low specific gravity oil occurs in sand-
stone beds, the deeper being the more important. The boreholes which
were put down to tap these light-oil beds met with them at depths of
from 800 to 1200 feet. The heavy oil of the upper beds is found at
depths of from 300 to 350 feet. This oil when raised to the surface has
a temperature of from 17° to 18° C., has a strong sulphuretted-hydrogen
smell, and contains much water, from which it can only be separated
with difficulty. On distillation it yields about 13 to 17 per cent. of a
bad illuminating oil. Formerly this oil was refined at Noworzossyk,
but it is now mostly employed in its raw state for lubricating purposes.
A pipe-line connects the wells with the Hinskaja station, where the oil
is allowed to flow direct into tank-waggons.

Oil is found at other places along the Caucasus coast of the Black Sea.
Of these the author mentions the valley of the Kudako River. Here
the oil yields from 10 to 12 per cent. of benzene, 6 of gasolene, and
from 33 to 37·5 per cent. of illuminating oil. Not far from this deposit

is another which has yielded small quantities of oil having a specific gravity of from 0·814 to 0·822. At many other places, too, the occurrence of oil has been noted, but the petroleum deposits of the Kuban Government are still practically almost entirely undeveloped. In the valley of the Kudako River, ten miles from the Krimskaja railway station, a borehole was put down in 1886 to a depth of 120 feet, and at this depth the oil rose to a height of 15 feet above the surface, 1500 poods of oil being the daily yield. On deepening the well to 183 feet the daily output rose to 3000 poods, and a further deepening of the well to 225 feet resulted in an oil outflow which for two months amounted to 5000 poods a day, the oil having the specific gravity of 0·865. In 1890 there were seven boreholes in this neighbourhood, but their total output for the year was only 38,568 poods of raw oil.

The Petroleum Industry of the Ter District.—K. J. Tumsky [*] observes that the Russian petroleum industry originated in the Ter district. Although the arrangements in use were very primitive, the output at Grosno amounted in the first fifty years to 370,000 poods. Since then boring has been introduced. The most productive well was bored in September 1895, and from this the oil spouted a hundred yards into the air. In the first few days the yield of oil reached 800,000 poods a day. All investigations have shown that the Grosno oil contains much benzene, but is poor in petroleum. By driving off over a free fire without steam 15 per cent. of benzene, there remains a residue having the specific gravity 0·9155, which is a valuable oil for fuel purposes.

Caucasian Bitumen.—Close to the village of Nagarebi, near the town of Kutais in the Caucasus, are limestone beds, from the cracks and fissures in which bitumen exudes.[†] Coal occurs in the neighbourhood, and as a connection between coal and shale is assumed, it is probable that the bitumen may be considered as a distillation product of coal seams occurring at greater depth. It is certain that it is not a naphtha product. In those places where the limestone is directly exposed to the action of the sun's rays, the bitumen exudes in relatively large quantities. These spots attract large swarms of bees, which store the bitumen and utilise it in the formation of wax. This is not observed anywhere else in the

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[*] *Techn. Sbornik; Trudy bak. otd. imp. russk. techn. obschtsch.*, 1896, vol. xi. p. 80; *Chemiker Zeitung*, vol. xx., Repertorium, p. 133.

[†] *Gorno Sawodski list.*, vol. viii. p. 2385.

Caucasus, and it is probable that it contains much paraffin and ozokerite-like constituents. The Nagarebi bitumen has, however, only recently been noted, and its chemical constitution has not yet been ascertained; nor has this bitumen thus far been mined for.

According to K. W. Charitschkoff [*] a new deposit of oil has been found in the Eastern Caucasus, about fifty miles north of Baku, on the Caspian Sea, at Chidersinde. The oil has a specific gravity of 0·866, and produces on distillation 60 per cent. of illuminating oil, and 12·4 per cent. of solar oil. The residue is not suitable for the manufacture of lubricating oil, but may be available as fuel. The chemical composition is given as 85·72 per cent. of carbon, 12·97 of hydrogen, and 0·13 of oxygen.

Oil in Tennessee.—According to E. J. Schmitz,[†] the oil territory is supposed to cover several counties in the State of Tennessee, following the general belt of the Appalachian system with its south-western trend. A map of the district is given. Several wells have been sunk with varying successes, of which authentic particulars are not in all cases available. The Bob's Bar well is stated to have struck oil at a depth of 270 feet, but the oil caught fire, and at present stands 50 feet below the surface. The oil is found in an easily drilled siliceous limestone, about 100 feet in thickness. A section of the well is given, and also of the Lacy well, which has been sunk to a depth of 1000 feet. The constituents of one sample of oil are given, showing 51·6 per cent. of heavy paraffin oils, with no rhigolene or gasolene. It is estimated that the Trenton, Cincinnati, or Nashville horizon may be struck at depths from 1380 to 1850 feet, about 30 to 35 miles east of Obey River.

The Salt Creek Oilfield, Wyoming.—W. C. Knight [‡] states that the Salt Creek Oilfield was the first to be worked of the many fields in Wyoming. It lies in Natrona and Johnson counties, and covers about 18 by 30 miles. The country is cut up by deep gulches, timber is scarce, and water is bad and scarce except in spring. Oil was not struck until 1890. The first refinery commenced working early in 1895. The field is a gentle anticlinal fold, with a north-west and south-east axis over 15 miles in length. The dip is about 6° to the north-east, but less on the other side. The oil occurs in either lower Fox Hills or upper Ft. Benton sandstone of the Cretaceous age. Pro-

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[*] *Imperial Russian Technical Society at Baku,* July 11, 1895; *American Manufacturer,* vol. lviii. p. 158.

[†] *Engineering and Mining Journal,* vol. lxi. pp. 228-229.

[‡] *Ibid.,* pp. 87-89.

ducing wells vary from 900 to 1500 feet in depth. All the wells are pumped, owing to the viscosity of the oil. The specific gravity of the oil is 0·910. It is fluid at zero Centigrade. The output in 1895 was 7000 barrels, but it is expected to reach 50,000 barrels this year. At present the oil is hauled in mule waggons, of which some illustrations are given. A map of the district is appended.

The Asphalt Deposits of Hanover.—Deposits containing asphalt are found in two parts of Hanover.* These are at some distance from each other, one being in the neighbourhood of the town of Hanover, and the other on the south-western slopes of the Hils range. It was at the first mentioned deposit that the mining of this mineral was originally begun. Beds belonging to the upper Jurassic formation (malm) are found saturated with asphalt. They are mined by two companies, one of which solely employs open-cast. It is found that only those beds are saturated with bitumen, which in their original structure contained hollows in which the bitumen could collect. Clay beds and the more compact limestones could not absorb it and contain none. The less compact " oolitic beds " contain, on the other hand, up to as much as 18 per cent., and average from 12 to 14 per cent. Four beds of this are being worked at one working, their thicknesses varying from about 1 to 7 yards. At another working a bed 5 yards thick contains 8·80 per cent. of bituminous matter, 2·55 per cent. consisting of hydrocarbons with boiling points below 255° C. In ether the rock decomposes, but only very slowly, forming a grey powder, most of which is soluble in hydrochloric acid. At certain points in this bed, which is worked by deep mining, petroleum is found to collect. It does not drop from the roof or walls, but rises from below. About three tons are annually collected in this way. The bed itself smells strongly of petroleum.

At Waltersberg, in the second group of deposits, a bed 7 yards thick is mined. This is divided into two by a parting. The upper half is the richer, but the percentage of bitumen, even in this, does not exceed six. Other beds are also mentioned.

Russian Asphalt.—K. K. Lipinski † observes that the asphalt used in Russia has hitherto either been imported or has been obtained from the Schigulew range, but now the " acid tar " residues from lubricating

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, voL xliii. pp. 687–691.

† *Zap. imp. russk. techn. obschtsch.*, 1896, vol. xxx. No. II. p. 1–6 ; *Chemiker Zeitung*, vol. xx., Repertorium, p. 106.

oilworks are being used.   The Schigulew asphalt is being obtained from
a bituminous sandstone by boiling with water.   The material so obtained
still contains 65 per cent. of sandy and clayey additions.   To obtain
purer products the extraction with water must be repeated, and to ensure
a better deposition of the bitumen some sulphuric acid should be added
to the boiling water.   The marketable product so obtained still contains,
however, a considerable quantity of impurities.   A more perfect purifica-
tion could only be obtained by repeated fusions ; but, in the first place,
the product obtained would be too expensive, and, besides this, it would
be too soft at ordinary temperatures.   Just as soft, too, are the bitumens
obtained from the rocks by the use of a volatile extracting agent.   The
bitumen obtained from the "acid tar" in the refining of heavy oils
may, on the other hand, be prepared of any degree of hardness, and
have nothing like the same percentage admixture of foreign materials,
as they contain on an average 90 per cent. of bitumen.   After the excess
of acid has been got rid of by the aid of superheated steam, and the tar
neutralised and washed several times, the residue is quite free from acid.
The author considers the prejudice in favour of the natural asphalt, as
compared with these refinery residues, to be altogether wrong.

The Asphalt Deposits of Trinidad.—O. Lang * observes that
these deposits have been known for more than a century.   Not only are
these the most important known deposits of their kind, but they are of a
quite exceptional character.   Various reports had been made on them
from time to time, and the author refers to the British official report
by Wall and Sawkins on the Geology of Trinidad, which was published
in 1860, the earliest report extant dating from the year 1769, when the
asphalt lake was visited by A. Anderson, who estimates its circumference
at three miles.   Other descriptions are also referred to—by Nugent in
1807, Alexander in 1832, and by Manross in 1855.   The most recent
account is that of S. F. Peckham,† who visited Trinidad in March 1895.
He observes that as the vessel approached Point la Brea from the north-
west the asphalt reef, which forms a barrier against the sea, was easily
observable.   Asphalt heaps on the shore had softened under the heat
of the sun, and the lumps had partially run, forming compact masses.
The area of the asphalt lake is given by Peckham as $99\frac{1}{2}$ acres, but it is
probably larger, as its borders are hard to define.   The overflow is
carried away by a kind of glacier stream towards the sea.   In former

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliii. pp. 667-673.
† *American Journal of Science,* vol. l. pp. 33-51.

times overflows appear to have occurred in various directions, and the level of the lake has frequently been considerably higher than at present. The asphalt itself appears to have become harder and firmer during the 107 years covered by the several reports. At many "blowholes," however, asphalt rises in a perfectly fluid condition. The surface of the lake is divided by numerous fissures into a number of areas of very unequal size. Gas is constantly rising through the asphalt, and this flows gradually from the centre of the lake towards its sides. The lake is considered by Richardson and Peckham to fill the crater of a former mud volcano. The asphalt itself Peckham considers to have originated as a distillation product from lignite beds under the action of hot springs. The conditions in the island of Trinidad were identical with those which caused the large deposits of asphalt and pitch in California. Ninety per cent. of the insoluble inorganic matter contained in the asphalt consists of silica. Lang considers it doubtful whether lignite beds can have been the origin of the asphalt. Sketch plans and other further details are given in the paper.

In connection with this paper * the following quotation from "The Discovery of Guiana," as described by Sir Walter Raleigh, will be of interest. His account refers to the spring of 1595. He says: "We arrived at Trinidad on the 22nd of March, casting anchor at Point Curiapan, which the Spaniards call Punto de Gallo, which is situate in eight degrees or thereabouts. . . . From thence I rowed to another part, called by the naturals Piche, and by the Spaniards Tierra de Brea. . . . At this point called Tierra de Brea, or Piche, there is an abundance of stone pitch, that all the ships of the world may therewith be laden from thence, and we made trial of it in trimming our ships to be most excellent good, and melteth not with the sun as the pitch of Norway, and therefore for ships trading the south parts very profitable."

From this it would appear that the statement referred to in the abstract that the asphalt appears to have become harder and firmer in the course of time is open to question.

S. F. Peckham † finds that acetone cannot replace petroleum ether in the technical analysis of asphaltum because its solvent properties are different for bitumen, and it extracts non-bituminous bodies. The action approaches that of alcohol, and the author therefore does not agree with a method proposed by S. P. Sadtler.‡

* Note by Abstractors.

† *Journal of the Franklin Institute*, vol. cxli. pp. 219–223.

‡ *Ibid.*, vol. cxl. pp. 383–386.

VI.—*NATURAL GAS.*

Natural Gas in Indiana.—Leach,[*] as natural gas supervisor, in his first annual report to the State Geologist of Indiana, states that there is a greater tendency to economy of natural gas, and that prices are advancing. The gas territory originally covered 2000 square miles, but is now diminishing owing to the exhaustion of gas and the encroachment of salt water. The original rock pressure of 325 lbs. has now fallen to 230 lbs., and will diminish more rapidly in the future. The distribution system has improved, and the question of employing meters is demanding more attention, but up to the present the supply has always equalled the demand. Many thousand acres are still held in reserve.

A Natural Gas Pipe-Line.—It is stated [†] that the Philadelphia Natural Gas Company of Pittsburgh have nearly completed the longest and largest gas-line in the world, bringing their total up to over 1000 miles of pipe-line. The line in question is 101 miles long, and penetrates the gasfields of West Virginia. The first section from Pittsburgh is 14 miles long and 36 inches in diameter, laid at a depth of 4 feet. The second section is of 23-inch pipe and 5 miles long, whilst the remainder is 82 miles in length. Over 48 miles are now in use from the Greene county wells.

VII.—*ARTIFICIAL GAS.*

Gas-Producers.—In the Swindell gas-producer there are two inclined grates, at the bottom of which are pipes for superheating steam. These grates incline towards the centre but do not meet, and the ash drops through and between them into the bottom, which may contain water to form a water-seal or not as desired. The air supply is introduced behind the grates. The coal is fed by means of cylinders which slide backwards and forwards over holes in the top of the producer, the cover of these holes being attached to the cylinder so that the bell and hopper is dispensed with. Illustrations are given.[‡]

. [*] *Iron Trade Review*, vol. xxix. No. 5, p. 13.
[†] *Iron Age*, vol. lvi. p. 1321.   [‡] *Ibid.*, p. 1039.

Some illustrations of the Miller gas-producer have recently been published.* An analysis of the gas is given as follows :—

CO_2.	O.	CO.	H.	CH_4.	N.	Total.
0·0	8·4	30·4	44·7	10·5	6·0	100

For an output of a million feet daily the size of the plant is given as 15 by 11¾ by 16 feet in height. The producer is charged by six hoppers, each holding 300 lbs. of coal. The depth of hot coke is about 8 feet, and air is blown for about ten minutes after the steam. External views of the producer only are given.

C. F. Jenkin † has published an elaborate paper on the efficiencies of gas-producers. His experiments tend to confirm the statements which have been made by several writers on the subject, that a high temperature of the fuel at the bottom of the producer is advantageous, and leads to the use of a small grate or contracted area where the blast is admitted. This is probably only true when steam blast is used. The author has found that a blast pressure of about 30 to 40 mm. of water gave the best results. The best pressure probably depends on the grate area, depth of fuel-bed, area of producer, &c. The rate of working depends on the pressure employed to a great extent, but for a given rate of working the pressure may be considerably varied by opening up or ramming down the fuel with the poker. With some fuels it is advantageous to ram the fuel down with a flat-ended poker.

A low grate efficiency is easily recognised, but is not easily corrected. Continuous producers have, as a rule, a higher grate efficiency than those which require to be stopped periodically for cleaning. Various forms of continuous producers have been designed, some with open water-boshes such as the Dawson and Shiel producers, and one form of Ingham producer ; others with mechanical arrangements for extracting the ashes, as in one form of Wilson producer and the Taylor producer. To obtain a high grate efficiency the producer must be designed so that all the fuel must pass close to the blast admission before it reaches the ashpit, otherwise some coke will escape unburnt with the ashes. This point has been overlooked in some modern producers.

Examples are given to show how important a matter the efficiency of producers may be to a manufacturer. Examples are given of efficiencies of 45 per cent. and of 70 per cent. This means that one producer is

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* *Iron Age*, vol. lvii. p. 242.

† *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 328–351.

burning 70 tons of coal, while the other only burns 45 tons to give the same amount of heat. The second producer would save $\frac{25}{70}$, or more than 35 per cent. of the coal used in the first. The importance of such a saving in the coal bill need hardly be pointed out.

VIII.—COAL-MINING.

Deep Boring.—According to Köbrich,[*] the deepest borehole yet made is that put down by the Prussian Government at Paruschowitz near Rybnik, in Upper Silesia. The boring was begun on 26th January 1892, and was finished on 17th May 1893, after having attained a depth of 2003·34 metres (6572·71 feet). The borehole was put down to search for coal, of which no less than 83 seams were encountered, with a total thickness of 293½ feet. The total cost was £3761, or 37s. 6d. per metre. The increase of temperature was 1° C. for 34·1 metres (1° F. for 62·1 feet).

The Raky method of deep boring is described by M. Buhrbanck.[†] The rods of the percussive borer hang from a spring pole, the end of which is moved by a cam. The driving is effected by a belt with tension pulley, and on this being set free the boring cutter falls.

Köbrich [‡] describes the various methods that have been adopted for determining the strike of strata in the depths of a borehole.

A description has been published [§] of methods of securing small objects in deep boreholes, and H. Thumann [||] discusses the methods of rendering deep boreholes water-tight.

T. Ebert [¶] states that deep borings in the Upper Silesian coalfields showed the presence above the Carboniferous series of Triassic and Tertiary formations and Diluvium. These he describes.

Shaft - Sinking.—A detailed description has been published by Lengemann and Meinicke [**] of the sinking of the Kaiser Wilhelm II. shaft at Clausthal in the Hartz. Full particulars are given of the shaft

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen, Vereins Mittheilungen*, 1895, p. 108 ; *Glückauf*, vol. xxxi. pp. 1273–1277.

[†] *Glückauf*, vol. xxxii. pp. 225–229, with five illustrations.

[‡] *Ibid.*, vol. xxxi. pp. 1312–1315.   [§] *Ibid.*, p. 1342.

[||] *Ibid.*, pp. 1353–1354.   [¶] *Ibid.*, vol. xxxii. p. 119.

[**] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlii. pp. 227–243, with eight plates.

equipment, machinery, man engine, air compressors, dynamos, winding engine, and the hydraulic engines by which the machinery is driven.

K. A. Weithofer * describes the sinking of the Bayer shaft of the West Bohemian Mining Company at Pilsen. The shaft is 440 yards deep.

L. Thiriart † describes the simultaneous sinking and tubbing of the Fanny shaft of the Patience and Beaujonc collieries, Belgium. The shaft is 14 feet in diameter, and the cost of the complete shaft did not exceed £22 per metre.

Descriptions have been published ‡ of the method of sinking shafts by means of compressed air and by grab-dredging.

According to Klose,§ at the Von der Heydt Colliery at Saarbrücken, it has been found necessary to sink a new winding-shaft, the Kirschbeck shaft No. 3, for lowering and raising 1000 men. The shaft is rectangular in section, its internal dimensions being 12 feet 3 inches by 8 feet 2 inches. In order to accelerate the work, a rise was put up from the second deep level. The work proceeded very slowly. It began on 1st October 1890, and ceased at the end of May 1891, when the sinking was only 39 feet distant. Altogether in 179 working days 177 feet 2 inches were risen, or only 11·7 inches per day. The sinking began on 20th July 1890, and was carried out, in shale and soft sandstone as well as in hard conglomerate, without difficulty. In July 1891 the holing was effected at a depth of 750 feet with 325 working days. The average distance sunk per day was 27·5 inches. The cost was £18, 10s. per yard. The original idea was to line the shaft with brickwork. The successful adoption of cement bricks at a neighbouring colliery led to the introduction of that method of lining. The bricks consist of a mixture of coarse gravel, washed Moselle sand, and Portland cement, slightly moistened and stamped in an iron mould. The hardening is effected in the open air with frequent moistening with water. The bricks are 39 inches high and 13¾ inches thick. The section of the wall was divided into eighteen equal parts, so that sixteen ordinary shaft bricks and two specially shaped corner bricks were used. A depression at the top of each brick received a ridge at the base of the one above it. A brick of the dimensions mentioned weighed 1102 lbs., and a corner stone 1432 lbs. The total cost for sinking and lining was £10,674, 2s.,

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1896, p. 101, with plate.

† *Revue Universelle des Mines*, vol. xxxii. pp. 113–128.

‡ *Engineering*, vol. lxi. pp. 109, 399.

§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xliii. p. 10.

from which the value of the recovered temporary timber, which was utilised elsewhere, may be excluded, leaving an amount equivalent to £38, 10s. per yard.

In an exhaustive memoir, covering 137 pages, with 14 plates, Saclier and Waymel * describe the sinking of the Vicq pits of the Anzin Company by the Poetsch freezing process.

F. Schmidt † describes the various freezing machines that have been in successful use, and gives details of the recent applications of the freezing process for sinking through quicksands in France.

Some excellent underground photographs of views in the Pentrich collieries, Derbyshire, have been published.‡ The series comprises Hartington pit bottom, gate and coal face undercutting, bringing coal to pit bottom, Speedwell pit bottom, refuge hole, train of coal coming up incline, and air crossing.

Rapid Winding of Coal.—The Nottingham Colliery in Pennsylvania, belonging to the Lehigh and Wilkes Barre Coal Company, has made a record in raising coal from one shaft.§ There are two cages in the shaft counterbalancing each other, carrying waggons containing a little over two tons each. About 1200 waggons, or 2600 tons, are wound per day of ten hours. The shaft is 300 feet deep below the ground level, or 405 feet in depth from the landing platform at the top of the breaker. The hoisting engine has a pair of cylinders, 26 inch diameter and 5 feet stroke, and the hoisting rope winds on conical drums. From the bottom of the mine the workings extend over a 5° slope for more than a mile underground, running under the Susquehanna River. The tail-rope system of haulage is used in the mine. Pumping is done by compressed air, by which is avoided the great loss due to the condensation in long lines of steam - pipe. The compressed air is furnished by a set of Ingersoll-Sergeant piston inlet air-compressors, with steam-cylinders 28 inches by 48 inches, with Corliss valve gear, and air cylinders 34½ inches by 48. The steam pressure is 110 lbs. to 115 lbs., and the air pressure 50 lbs. The capacity is 10,500 cubic feet of air per minute. Steam is furnished to the compressor by four Babcock and Wilcox boilers of 250 horse-power each.

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* *Bulletin de la Société de l'Industrie Minérale*, vol. ix. p. 27. A full abstract of this paper is given in the *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. p. 541.

† *Bulletin de la Société de l'Industrie Minérale*, vol. ix. pp. 273–416.

‡ *The Engineer*, vol. lxxxi. p. 316.

§ *Ibid.*, vol. lxxxi. p. 148.

Winding in Upcast Shafts.—A. Reid * discusses the method of closing the tops of upcast shafts, and describes the one devised by himself, at work for the last two years at Ffrwd, No. 3 pit. A wrought iron casing enclosing the cage, with a little clearance all round, is built into the pit, and rendered air-tight from its bottom up to the landing plates. The cage, as it enters, relieves the pressure on the door at the top. It is lightly built of wood, and only weighs 1 cwt. A buffer mounted on the rope above the capping lifts the door, and the cage itself closes the shaft when the door is lifted.

Hydraulic Winding Device at St. Eloy.—According to Baudrey † at the St. Eloy Colliery, near St. Etienne, an ingenious arrangement has been adopted for raising the empty cages, and for lowering full ones containing filling material. It consists of a horizontal double-cylinder pump, with pistons forcing the water backwards and forwards in a closed circuit at a speed which can be varied by throttling the area of the connecting channel.

Safety Catches.—Drawings have been published ‡ of an elastic safety catch for colliery cages. Two long steel wire brushes are fixed to the cage, and in the event of the winding-rope breaking, are pressed against racks attached to the guides.

Siemens § describes the various safety appliances for preventing overwinding.

Shaft Gates.—W. Hay ‖ describes some fencing gates for a two-decked cage. The upper and lower gates are connected by chains passing over a pulley, and nearly balance each other. The top gate is lifted by the cage, and allows the bottom one to fall through a space provided in the bottom landing. Some objections were taken to this form in the discussion.

Winding - Engines. — B. Woodworth and W. G. Cowlishaw ¶ describe the Woodworth system of progressive and automatic cut-off

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* *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 367-371, with one plate.

† *Comptes Rendus de la Société de l'Industrie Minérale,* 1895, pp. 272-274, with two illustrations.

‡ *Portefeuille Economique des Machines,* vol. iv. pp. 181-184.

§ *Glückauf,* vol. xxxi. p. 1227.

‖ *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 480-482, with one plate.

¶ *Ibid.,* pp. 470-472, with one plate.

gear for winding-engines. This gear has been applied at the Sneyd Collieries.

Köttgen * gives the results of experiments with an electrically-driven winding-winch.

Schulte † describes in detail the new shaft equipment of the Preussen Colliery of the Harpener Colliery Company. The cages have four decks, each carrying two waggons.

In a highly mathematical paper, A. Godeaux ‡ discusses the form that should be given to the keps for the reception of colliery cages.

Underground Haulage.—F. W. Bond § argues in favour of rope haulage. Haulage with electric locomotives, he considers, involves expensive track, heavy timbering, special machinery, and handling of trains, whilst the cost of equipment is greater than for a rope haulage system. The tail-rope system also requires that trains shall be dealt with, that high speed shall be maintained, and that the track shall be good. The endless-rope single-truck system obviates all these objectionable features.

L. Stockett ‖ discusses the best forms of mine railways and trucks. He adopted a 33-inch gauge and a 12-lb. steel rail. The conditions of long-wall mining in the Illinois coalfield require a narrow low truck, with open ends for convenience in loading. For the body of the truck, it was decided to use steel ¼-inch thick in one sheet, 5 feet wide and 5 feet 6 inches long, bent to shape with a radius of 1 inch at the corners. Dimensioned sketches of the steel plate truck are given in the paper.

J. Jicinsky ¶ gives descriptions of various installations of mechanical haulage with endless chain, with full details of cost.

T. E. Hughes ** states that in the bituminous coal districts there are three systems of haulage chiefly employed—the tail-rope, the endless rope, and the electric systems. He strenuously advocates tail-rope haulage for use under nearly all circumstances, and describes two successful plants on this system. In one near Pittsburgh, the main rope is 10,500 feet and the tail-rope 21,000 feet long. The engines are 14 by 14 inches,

* *Glückauf*, vol. xxxii. p. 97, with five illustrations.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 153–154.

‡ *Revue Universelle des Mines*, vol. xxxi. pp. 243–249.

§ *Journal of the Illinois Mining Institute*, vol. iii. pp. 117–122.

‖ *Ibid.*, pp. 86–97.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 45.

** Paper read before the Ohio Institute of Mining Engineers, through the *Iron Trade Review*, vol. xxix. No. 5, p. 11.

drums 6 feet in diameter, steam pressure 80 lbs.; and the load per trip is 5300 lbs., of which 4000 lbs. is coal. The road is nearly level. In the second plant, the engines are 20 by 30 inches, geared 3 to 1, and develop 450 horse-power. The road is 9000 feet long, with a maximum grade of 1 in 20 against the load. The author prefers the standard lay of rope to the Lang lay.

F. G. Meachem * has collected some statistics of horse-feed at various collieries, and gives them in tabular form for thin and thick seams. A model feed for working under these two conditions is given at a cost of seven and eight shillings weekly.

The author, in another contribution, † deals with the poisoning of horses by *lathyrus sativus*, a kind of vetch, of which the seed is some-times found in peas.

P. Vanhassel ‡ describes and illustrates the principal forms of pulley used for self-acting inclines, referring specially to a pulley of his own design, which is claimed to present considerable advantages.

F. Koepe § describes the system of electrical haulage used at the Ewald Colliery at Harten, in Westphalia. A main road 2400 yards in length, and side roads 850 yards in length, are furnished with rope haulage, the haulage drums being driven by electromotors.

An illustration is given of an electric locomotive used at the Vinton Colliery, Cambria, Pennsylvania. It is worked on the overhead conductor system.||

Electricity in Mining.—I. Meachem ¶ describes the electric power plant installed at the Haden Hill Colliery. An old horizontal winding engine was altered to run at 42 strokes per minute, so as to drive a haulage dynamo at 800 revolutions, and a lighting dynamo at 840 revolutions. The former develops 75 amperes at 450 volts, or 45 horse-power, and the latter $54\frac{1}{2}$ amperes at 220 volts, or 16 horse-power. Armoured concentric cables are used as conductors. The motor runs at 700 revolutions, and is speeded down with belting and spur gearing, so that the rope-driving pulley runs at $4\frac{1}{2}$ revolutions per minute. The armature of the motor and generator are interchangeable.

* *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 187–188.
† *Ibid.,* pp. 183–186.
‡ *Revue Universelle des Mines,* vol. xxxi. pp. 232–242; *Bulletin de la Société de l'Industrie Minérale,* vol. ix. p. 149.
§ *Glückauf,* vol. xxxii. pp. 244–248, with two illustrations.
|| *Engineering and Mining Journal,* vol. lxi. p. 231.
¶ *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 178–182.

The haulage motor is 660 feet in bye, and 3300 feet from the generating station.   About 500 tons daily is dealt with on two inclines.   A fan and pump are also driven electrically.   The application of electricity to haulage alone was not expected to be productive of any saving, but the advantages of the other uses of electricity overbalanced all other considerations.

C. Pfankuch * discusses the use of electricity as a motive power in mines and metallurgical works.   He deals with the subject historically, giving in outline the history of the evolution of this form of motive power as applied to the mining and metallurgical industries.   He first considers the matter from a theoretical point of view, and shows that in various directions a saving can be effected by the use of electricity as a motive power in mining and in metallurgical operations.   He gives reasons for this, together with examples.   He then passes in review the various kinds of electrical appliances that are in use, and next describes several different installations where electricity is employed as a motive power in various ways.

S. F. Walker † has published a series of articles describing the different apparatus that are used for electric lighting and transmission of power in mines, the principles upon which they are constructed, the various arrangements employed in connection with the different apparatus, and the principal sources of failure.

R. Kennedy ‡ describes some new forms of machinery especially designed for applying electricity as a motive power in collieries, and discusses both continuous current plants and alternating current plants from a comparative point of view.   The former were mostly used in this country because of patent rights, and because they are better known, but alternating currents are used in America and on the Continent.   The author believes that a combination of the two systems would meet every requirement.   Lighting currents cannot well be used over 250 volts, but for motors 500 volts is preferable, and two continuous currents of these potentials may be given by a special four-pole dynamo, which is described.   A generator is also described for producing both continuous and alternating currents, so that either one or both kinds of motors can be used at the same time, and high or low pressure currents can be readily obtained from the alternating currents of this combined system

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* *Stahl und Eisen*, vol. xvi. pp. 184-199, nineteen illustrations.

† *Colliery Guardian*, vol. lxx. pp. 741, 1029-1030 ; vol. lxxi. pp. 18, 112-113, 210, 306-307.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 98-106.

by the use of transformers. The author's form of polyphase motor, and also a reciprocating motor for pumps, are described.

The Treatment of Mine Timber.—R. Martin [*] describes the method of treating timber at the Niddrie collieries by boiling it in a concentrated solution of seven parts of common salt to one part of chloride of magnesium. Two rectangular boilers, 19 feet long by 4 feet wide and 3 feet deep, are kept nearly boiling by a fire of dross coal. One tank is emptied and filled daily with all timber used in the mine, so that it is treated for about two days. It is then dried by a few days' exposure before use. Timber thus treated has lasted some two years when ordinary timber only lasts ten months, and, in addition, is less liable to take fire, as the salt keeps it damp.

The following method of creosoting [†] is employed in the Sables d'Olonne Works. The wood is put into a sheet-iron cylinder, the cubic capacity of which is about 5 cubic metres (176 cubic feet). The cylinder is closed, and for an hour and a half hard wood is subjected to a temperature of from 60° C. to 70° C., and soft to one of from 100° C. to 110° C. Next a partial vacuum is made in the cylinder, the former temperatures being maintained. The heating causes the pores of the wood to enlarge, and this, with the diminution of pressure, facilitates the discharge of the contained water and gas. When a sufficient vacuum has been produced, the creosote, heated to 60°, is forced into the cylinder by pumps until a pressure of ten atmospheres is attained.

The Use of Steel Girders in Mines.—E. Thompson [‡] advocates the further use of steel girders in mines, and shows that, although the conditions vary considerably from those obtaining in building construction, yet they show equally satisfactory comparative results. The sections of girders in general use in main roads are as follows :—

Depth of Girder, inches.	Width of Flange, inches.	Thickness of Web, inch.	Weight per Foot, lbs.	Estimated Safe Dead Distributed Load for an 8 feet space, tons.
5	4	⅜	16¾	7
5	4	½	22	9
6	4½	½	24	12

* *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 531–536.
† *L'Echo des Mines et de la Métallurgie,* vol. xxii. p. 494.
‡ *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 272–279.

The safe loads are calculated at one-third of the breaking weight. Under comparatively equal loads, the length of bars of the above sizes may be 6 to 8, 8 to 10, and 10 to 14 feet. At £5 per ton, these cost 9d., 12d., and 13d. per foot. The cost, as compared with larch bars to maintain equal weights, is not very much greater, and they give a considerable saving in the height of the road and by their durability. In damp places the girders may be tarred. It is especially necessary to keep the girders upright, and for this purpose timber distance pieces should be placed between them. A shoe should also be used when timber props are employed. When girder props are used, clips or other devices are used to avoid cutting them to make the joints.

Hand-Boring Machines.—L. Thiriart * describes and illustrates a number of hand-drills of recent design. Special reference is made to the Elliot, Thomas, and Demany drills.

Explosives and Blasting.—Further communications on the subject of explosives have appeared from Winkhaus.† In the first of these he deals with the blasting efficiency of explosives, and records the results obtained with the lead block method with different kinds of explosives. In the second he deals with safety explosives and the report of the Prussian Fire-damp Commission, together with similar reports. H. Lohmann ‡ agrees with his opinions, and joins with him in urging that further experiments should be undertaken.

J. von Lauer § discusses the use of detonators in fiery mines, passing in review the earlier attempts made to explode nitro-glycerine, giving in detail the results of Abel's and Trauzl's experiments in 1869 and 1870, and the Nobel method of explosion. He then passes to a consideration of the detonators subsequently introduced into practice. In 1887 many manufacturers placed heavily-charged detonators on the market, as it had been proved that the power of any given quantity of an explosive was greatly increased by increasing the strength of the initial impulse. Detonators of eight different degrees of strength were made.

J. von Lauer ‖ considers the use of percussion igniters in collieries of a fiery character. He deals with the question historically, and then

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* *Revue Universelle des Mines,* vol. xxxii. pp. 62-73, with twenty-two illustrations.

† *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 264-271, 337-350.

‡ *Ibid.,* pp. 351-353.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliii. pp. 511-517, 529-531, with plate.

‖ *Ibid.,* pp. 693-697.

considers the igniting methods of Gubovit, Hausse, Nawratil, Tomann and Tirmann, and the newer one of Tirmann, an improvement on the one just mentioned. Even the most recent igniter, he observes, showed in practice 3·3 per cent. of misfires, the cause being mainly too weak a charge of explosive in the caps. By using stronger caps the percentage of misfires has been reduced to 1·25 per cent. A sketch is given showing the arrangement of the Tirmann and Tirmann-Tomann igniters. The Tirmann method consists in compressing a spring, which is then released, and drives a point into the cap. The other does not very greatly differ from this in mechanical arrangement. The author criticises the Tirmann igniter, raising various objections to its use.

L. Jaroljmek * has devised a method of blasting which is calculated to render the ignition of explosives in boreholes in fiery mines absolutely free from danger. A quicklime cartridge and a dynamite cartridge are connected, the slaked lime heating a primer sufficiently to fire off the detonator embedded in the dynamite, or the increase in volume acting on a friction-igniting apparatus. The compound cartridge is enclosed in a bag of cotton woven like a wick. Experiments were made in a gallery containing 7 per cent. of marsh gas and a large quantity of coal dust kept in motion, and in no case did the explosion of the cartridge fire the gases or the dust, the flame being confined to the interior of the cartridge, and stopped both by the slaked lime and the water in the borehole at its upper end.

Coal-Cutting Machinery.—The development in the use of coal-cutting machinery has been much slower than was at one time expected, but the introduction of electric transmission of power has given it a certain impetus. At the beginning too much was expected of the machines, and one of the obstacles to advance was the absence of reliable data. A series of experiments has been conducted by R. M. Haseltine, and the results are embodied in his last annual report as chief inspector of mines in Ohio. The average power used in cutting with the different machines varied, according to local conditions and apparatus, from 8·6 to 22·7 horse-power, the power required to undercut one square foot per minute fluctuating between 4·2 and 12·2 horse-power. The general average horse-power required by bar machines was 18·7, while for chain machines it was 14·4. Coal-cutting machinery has steadily gained ground in Ohio. In 1889 about a twelfth of the coal was obtained by machinery, and in 1894 about a fifth of the total.

* *Berg- und Hüttenmännisches Jahrbuch des k.k. Bergakademien*, vol. xliii. p. 381.

Working Thin Seams.—F. Cambessédès * gives an exhaustive account, fully illustrated by plans and sections, of the methods of working thin seams in the Franco-Belgian coalfield. The average thickness of the seams in this field is generally under a metre. At Liége it is 0·73, Namur 0·61, Charleroi 0·72, Centre 0·60, Mons 0·50, Nord 0·75, and over a metre in the Pas de Calais. Most of the seams contain partings, and there is, as a rule, sufficient material extracted to pack the workings. It is generally the practice to work out the coal and pack the goaf as the roads are pushed forward ; but sometimes, and especially when the seams approach a metre in thickness, the roads are driven first over a considerable area, and the coal subsequently worked in the broken. It is impossible within the limit of an abstract suitable for this volume to more than indicate the scope of this paper, as the different methods of working and their modifications are so exceedingly numerous. Most of these methods are a modification of the long wall. A special feature of the paper consists in tabulated statements of the different seams in various districts, giving a section of the seam, its dip, cleat, yield, and some particulars of working.

Mining Thick Seams of Brown Coal.—H. Gutmann † illustrates a method for the mining of thick seams of brown coal. The best of all such methods he considers to be that of Köflach in cases where no quicksands have to be dealt with. Such conditions as those he deals with exist in the brown coal districts of North-West Bohemia. The chief advantages are : (1) that very little wood is required, the cost of this being only about 2½d. for every ton of brown coal raised ; (2) the output per miner is high. Thus, at Wöllau, where the brown coal is closely interwoven with tough lignite, thus rendering the work very difficult, a miner will raise five waggons, each containing 0·65 ton of brown coal. (3) Arrangements can be made for preparing in advance for heavy and irregular market demands. The author describes the method in detail with the aid of a number of sketches, and observes that seams up to 20 yards and more in thickness can be completely removed. The author proposes a modification of the method, and sums up the general advantages possessed by the methods he describes.

Remy ‡ describes the appliances employed in the brown coal mines

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* *Bulletin de la Société de l'Industrie Minérale,* vol. ix. pp. 529-627, 733–814.

† *Osterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliii. pp. 497–500, with four illustrations.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate,* vol. xliv. pp. 55–73.

of North-West Bohemia. The memoir is divided into the following sections :—(1) Occurrence and statistics of brown coal; (2) Exploitation of brown coal by quarrying and by mining; (3) Haulage and winding; (4) Screening and loading; (5) Drainage; (6) Ventilation; (7) Boilers.

Pumping Appliances.—P. R. Björling * has continued his series of illustrated articles on colliery pumps and pumping machinery.

Drawings have been published † of the underground pumps at the Viaduc Colliery at Gagnières. The installation consists of a double plunger pump, for lifting 6600 gallons of water to a height of 984 feet, driven by a tandem engine.

R. Halberstadt ‡ discusses the unwatering of flooded mines; and other memoirs recently published describe the drainage of the South Staffordshire mines, § the underground electrically-driven pumps at the Friedlicher Nachbar Colliery at Linden in Westphalia,‖ and a Newcomen pump, dating from 1745, which is still in use.¶

Illustrations have also been published ** of a Davey compound engine working on the Cornish cycle.

Mine Stoppings.—Instead of building stoppings of brick or stone laid in mortar, Callaghan †† proposes to construct them in a more yielding form, so that they will temporarily give way in case of an explosion, so as to break its force. In one mine, with this end in view, they are formed as somewhat heavy doors swung from hinges at the top. The doors are made of 2-inch plank, and the seams are padded with canvas. A sill about 18 inches high is laid on the floor, and the door can open from either side with a slight exertion of force, but closes by its own weight, thus restoring the ventilation. These doors have not been tested by a gas explosion, but have given good results during rock blasting.

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* *Colliery Guardian*, vol. lxx. pp. 732-733, 780-781, 828-829, 972-973, 1021-1022, 1068-1069.
† *Portefeuille Economique des Machines*, vol. iv. pp. 165-170.
‡ *Colliery Engineer*, vol. xvi. p. 56.
§ *Iron and Coal Trades Review*, vol. li. p. 362.
‖ *Glückauf*, vol. xxxi. p. 1219; *Bergbau*, vol. ix. p. 5.
¶ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxix. p. 1362.
** *Engineer*, vol. lxxxi. p. 84.
†† Paper read before the Western Pennsylvania Mining Institute, through the *American Manufacturer*, vol. lviii. p. 372.

Ventilating Appliances.—The Mortier fan * is described by Von Ihering, who gives drawings of the fan and expounds the theory of its action. E. Wolff † also describes this fan, and a detailed description of the Capell fan has been published.‡

E. Gosseries § describes the installation of a Guibal fan, 19 feet 8 inches in diameter, at the St. Theodore shaft of the Sacré Madame Colliery at Dampremy, one of the mines visited by the Iron and Steel Institute during the Belgian meeting in 1895.

A German translation of T. Guibal's lectures on mine ventilation has been published, ‖ and several exhaustive memoirs on the theory of mine ventilation have appeared.¶

The object of the experiments recorded by H. Heenan and W. Gilbert ** was to determine the best form of fan-blade and fan-case, and the most economical diameter and speed of a fan to produce any required volume of air at a given pressure. The comparative output of fans of the same type, but differing in size, showed that, if they were run at the same tip-speed and produced the same water-gauge, the air-discharge would be proportional to the centre section of the fan, that is, to the diameter multiplied by the width. A series of tests were made to determine the efficiency of an expanding chimney, the sides of which could be set at any desired angle to the centre line of the tube. The efficiency for any angle was obtained by dividing the vacuum observed at the throat of the chimney by the calculated vacuum due to the reduction of velocity of the air as it passed from the inlet to the outlet of the chimney. The results of the tests showed that the angle on each side might be as much as 15° without loss of efficiency. The air speed recommended at the outlet was 20 feet per second, and the efficiency with this speed varied between 0·43 for 6° opening and 0·42 for 15° opening on each side.

Mine Ventilation.—T. L. Elwen †† has repeated the experiments previously made by him ‡‡ on the resistances of air currents in mines, and in this repetition he made use of the König water-gauge side by side

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* *Glückauf*, vol. xxxii. p. 217, with two plates and one illustration.   Compare *Journal of the Iron and Steel Institute*, 1892, No. II. pp. 408.

† *Glückauf*, vol. xxxi. pp. 1371–1376, with eight illustrations.

‡ *Colliery Engineer*, vol. xvi. p. 80.

§ *Revue Universelle des Mines*, vol. xxxi. pp. 211–231.

‖ *Glückauf*, vol. xxxi. p. 1148.

¶ *Kohleninteressent*, 1895, pp. 149, 162, 170, 180.

** *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 272–325.

†† *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 62–66.

‡‡ *Journal of the Iron and Steel Institute*, 1895, No. I., p. 363.

with the ordinary gauge. The previous results were confirmed, showing a definite loss of pressure caused by an obstruction beyond that due to friction.

Uthemann * describes the successful results recently obtained in the Saarbrücken collieries with separate ventilation. The plan adopted consists in separating the working places from the air current created by the main fan, and in ventilating them by means of special arrangements.

Photometric Value of Illuminants in Mines.—In a lengthy and valuable paper, A. H. Stokes † has recorded the results of a large number of experiments made to determine the relative amount of light obtained from the illuminants used in mines, to define their commercial value, to point out certain adjuncts for increasing their light, and to call attention to defects and dangers which occasionally accompany their use. Experiments were made to ascertain the light intensity of safety-lamps and candles as compared with a standard candle ; safety-lamps and candles were also compared with each other, and their relative light-giving intensities ascertained. After describing the apparatus and materials used, the experiments are described in detail, and the results set forth in thirteen tables. The various parts and accessories of lamps, together with oils, candles, and particulars relating to them, are then considered, and finally it is pointed out that the price is not a criterion of the value of an oil.

The Determination of Fire-Damp.—Hardy ‡ gives a full description of his apparatus for determining the percentage of fire-damp in air by means of the beats produced by the notes of two whistles, one blown with pure air and the other with the air of the mine. He describes means for equalising the temperature and removing carbonic anhydride and moisture, in order to obviate those sources of error, and also describes an indicator to work at a distance, and an automatic registering apparatus.

Coquillon § describes a modified form of apparatus for determining the percentage of fire-damp in air. It is of the eudometric type, with a large receiver containing, near the bottom, a platinum spiral heated by an electric current. The diminution of volume is measured by the

* *Glückauf*, vol. xxxi. pp. 1209–1213.
† *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 135–160.
‡ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1896, pp. 22–32.
§ *Ibid.*, pp. 32–36, with plate.

rise of water in a small tube at the bottom. Lebreton points out objections to this form.

S. Reichenberg [*] describes and illustrates an apparatus for the examination of air containing marsh gas. It is based on the principle of the Coquillon apparatus. It comprises a combustion tube, containing a platinum spiral, which is heated to redness electrically, and absorption tube and measuring apparatus. The apparatus as described does not appear to offer any advantages over other similar appliances, or to be of practical value in fire-damp testing.[†]

P. Petit [‡] describes an apparatus, which he calls the "auto-capteur," for automatically taking a number of samples of air, in which the percentage of fire-damp may afterwards be determined, so that a curve can be plotted to show the evolution of gas at any point where the apparatus has been placed. It consists of a number of sampling vessels connected to a reservoir, which is of conical shape, so that the flow of water from it will proceed at a constant rate, and thus give an exact sample of the air during the period that any sample is being collected. When the water level falls below one of these vessels, it closes the air inlet to it automatically. The whole apparatus weighs about 27 lbs., and will take six samples.

E. Dieudonné [§] gives a short account of fire-damp and its explosive effects, and reproduces several underground photographs to illustrate a more or less popular article.

Several cases are recorded of outbursts of fire-damp in workings in which gas had not previously been detected. Thus Léon [||] gives a note on an outburst of gas met with on February 4, 1858, at the Peyrotte shaft of the Carmaux Colliery, and Leproux [¶] describes an outburst of gas met with on July 21, 1894, at the Marseille shaft of the Montrambert Colliery.

A. Simon [**] describes in detail the experiments made at the Liévin mines to measure the pressure of fire-damp in the coal.

Accidents in Mines.—A. Kirkup [††] discusses the question of the prevention of accidents in mines from explosions, falls, shafts, explosives,

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* *Chemiker Zeitung*, vol. xx. p. 240.
† *Ibid.*, p. 240 (editorial note).
‡ *Annales des Mines*, vol. ix. pp. 289–297, with one plate.
§ *Le Monde Moderne, Revue Mensuelle Illustrée*, vol. ii. pp. 850–858.
|| *Annales des Mines*, vol. viii. pp. 29–30.
¶ *Ibid.*, pp. 31–39.   ** *Ibid.*, pp. 218–231.
†† *Transactions of the Federated Institution of Mining Engineers*, vol. x. pp. 2–23.

and suffocation, tubs or engine planes, sundry underground causes, and surface accidents. The various conditions under which accidents from these causes occur are described, and the means which are generally adopted for their prevention or for minimising the likelihood of their occurrence are given, together with some suggestions for the better observance of these means.

Zörner * describes the various methods adopted in the Government collieries of the Saarbrücken coalfield for obviating the dangers caused by coal-dust. The relative advantages and the cost of the various appliances are given.

A. Zsigmondy † describes the fire-damp explosion at the Ronna shaft of the Anina collieries in Hungary on October 20, 1894.

Leproux ‡ gives a summary of the recent improvements in mining, reference being made to the precautions adopted to obviate coal-dust explosions, to rock drills, compressors and locomotives, railway waggons and signals.

Coal-Dust and High Explosives.—With a view to increasing the knowledge of the safe working of coal-mines, the North of England Mining Institute appointed a committee to experiment and report on a large number of high explosives. The committee have been at work for nearly a year, and their second report, dealing with the action of flameless explosives in mixtures of coal-dust and air, and coal-dust, air, and pit gas, has been published.§ A former report gave the results of experiments conducted in mixtures of gases and air alone, but the investigations are far less important than those conducted since, particularly as it has been finally demonstrated that an exceedingly small quantity of coal-dust is sufficient to cause an explosion, and the contention that it only constituted a danger when present in large quantities is proved to be entirely unfounded. This inquiry has revealed the fact that the presence of coal-dust in quantities varying from 32 parts to 1 produced almost identical results, a point which deserves attention.

The conclusions of the committee have been drawn up as follows :—

(1.) The high explosives—ammonite, ardeer powder, bellite, carbonite,

* *Glückauf*, vol. xxxi. pp. 1207-1208.

† *Bulletin de la Société de l'Industrie Minérale*, vol. ix. p. 161.

‡ *Bulletin de la Société d'Encouragement*, vol. x. pp. 1314-1335, with thirty-five illustrations.

§ "Report of the Proceedings of the Flameless Explosives Committee," Newcastle-on-Tyne, 1896.

roburite, securite, and westfalite—on detonation, produce evident flame.
(2.) The high explosives are liable to ignite either inflammable mixtures
of air and fire-damp, or air and coal-dust, or air, fire-damp, and coal-dust,
and therefore cannot be relied upon as ensuring absolute safety when
used in places where such mixtures are present. (3.) The explosives
are less liable than blasting powder to ignite inflammable mixtures of
air and fire-damp, air and coal-dust, and air, fire-damp, and coal-dust.
(4.) The experiments have shown that ignitions of mixtures of air
and coal-dust, with or without the presence of fire-damp, can be obtained
when there is present a much smaller quantity of coal-dust than has
been previously supposed to be necessary. (5.) It is essential that
similar examinations of the working places and precautions which are
in force in mines where blasting powder is used should be rigidly
observed when a high explosive is employed. (6.) In selecting a high
explosive for a mine, it should not be forgotten that the risk of explosion
is only lessened, and not abolished, by its use. (7.) In view of the
changes from time to time made in the proportions and constituents of
high explosives, it is desirable that the name of the explosive should be
printed on the wrapper of each cartridge, and that the date of manufac-
ture, and the proportion of the ingredients used in the manufacture of
the explosive, should be printed on the case of each packet of cartridges.
(8.) As these explosives alter in character if improperly kept, it is
necessary that every care should be taken in the storage, to ensure their
being maintained in good condition

Telephones in Mines.—A. W. Bennett * describes the use of tele-
phones for communication in mines, advocating some special types of
instruments, and dwelling upon the various systems of wiring, and pro-
poses the use of a cable containing a number of insulated wires, so that
any station may communicate with any other station.

A Deposit in Old Workings.—C. J. Murton and S. Shaw †
describe a deposit found in some old workings in the low main seam at
Delaval Colliery, Benwell, Northumberland. It occurs where the bottom
coal has been entirely removed, and especially when the top coal has also
been worked. The seam lies very flat, and has remained water-logged
for many years. The deposit is usually about 10 inches in thickness,
the upper 3 or 4 inches is white, and then there are alternating red

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* *Transactions of the Federated Institution of Mining Engineers,* vol. x. pp. 372–376.
† *Ibid.,* p. 67–71.

and white layers, becoming red at the bottom. In composition it is a hydrated silicate of lime and alumina. A similar deposit occurs in old workings at Tanfield Lea Colliery, Durham.

Some Fuel Problems.—J. D. Weeks * discusses some of the problems that bear on the question of fuel supply. The wonderful increase in production that has taken place within the present century is referred to, and the various estimates for its duration in England and America are briefly noted. Attention is then turned to the three factors of the mining of coal and its preparation for the market; the use of coal; and thirdly, the products of coal other than heat. In regard to the first point, the report of the Pennsylvania Commissioners on Waste of Coal-Mining † is quoted, and its lessons enforced. As for the second point, the comparative inefficiency of the present modes of utilisation are dwelt upon, and then reference is made to the extensive waste of by-products. In summing up, the author shows that in seams worked during the last fifty years, not more than 30 per cent. of the coal is extracted, and of this coal that is used, not more than 5 to 10 per cent. of its energy is employed ; that is, 3 per cent. at most of the energy of the coal in its bed is utilised.

The History of Coal-Mining.—W. H. Mungall ‡ gives some notes on the history of Scotch coal-mining. Mention is made of the several Acts passed in the second half of the sixteenth century to restrain the export of coal, as there were fears even at that time of the exhaustion of the coalfields. At the beginning of the seventeenth century the difficulties due to the increasing depth of working were becoming more acute. Water was probably first dealt with by the rag and chain pump. The improved bucket pump of Sir George Bruce is referred to, and in connection with that coal-owner the visit of King James in 1617 to his partly submarine mine is described. The various Acts of Parliament dealing with the colliers are also dealt with.

O. Vogel § continues his quotations from ancient works on coal, observing that the earliest mention of this substance was made by Theophrastus, 320 years before the Christian era, who wrote :—" Near Bina, in Thrace, there are very friable stones which are combustible, so

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* *Transactions of the American Institute of Mining Engineers,* Presidential address at the Atalanta meeting.
  † *Journal of the Iron and Steel Institute,* 1893, No. II. pp. 397-399.
  ‡ *Journal of the British Society of Mining Students,* vol. xviii. pp. 30-35.
  § *Glückauf,* vol. xxxii. pp. 281-287.

that they have long been used for fuel; but they give out a suffocating and disagreeable smell; moreover, in Sicily there are stones which burn with an asphaltic odour. The coals are dug for use because they burn like charcoal. They are found in Liguria, with amber, and also in Elis, near Olympia, and are chiefly used by smiths." Theophrastus was aware of spontaneous combustion, as he observes that broken coal, thrown into a heap and damped, kindles of itself in the sunshine. Writings before the middle of the sixteenth century, however, afford very slight information as to how far the world was acquainted with coal. For instance, Sicculus Flaccus wrote that coals were employed as landmarks; and St. Augustin states that they were much in request for all purposes. Biringuccio was the first to speak a little more definitely in his "Pyrotechnica," which appeared in 1540, observing: "I really believe that men can better dispense with ores than with fuel, on account of the manifold uses of the latter, and Nature has, in addition to the trees, in many places also provided stones which have the properties of charcoal, and by means of which iron is worked, the other metals smelted, and stones prepared so as to make lime for building." The earliest remarks as to the vegetable origin of coal are to be found in a memoir by the botanist Antoine de Jussieu on the fossil plant prints at Saint-Chaumont, which he read before the Paris Academy of Science in 1718. Distinction was first drawn between true coal and lignite in the middle of last century, whereas previously every rock that would burn was called coal.

Recent Progress in Mine - Surveying.—Bennett H. Brough [*] discusses the progress recently made in mine-surveying, referring specially to the various contrivances used for determining the variations of the magnetic needle. Considerable attention has been devoted to this subject in Germany, and magnetic observatories have been erected in most of the mining districts.

W. Lenz [†] has conducted a series of experiments on the action of electric currents on mine-surveying instruments. A point underground was selected at a horizontal distance of some 100 yards from the rails of the Bochum-Herne electric railway, and 434 yards below it. There, by means of a Fennel's magnetometer with quartz fibre suspension, a series of observations of variation were made, based on a fixed line. The magnetometer was previously compared for a long period with

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[*] *Engineering Review*, vol. iii. p. 279.
[†] *Glückauf*, vol. xxxi. p. 1197.

the apparatus in the Bochum town - park, and the two instruments were found to coincide almost exactly. The first observation in September 1895 was made by day, the second by night, when the line was free from current, and the last again by day. Whilst the curve of the day results exhibited great irregularities, that of the night results was perfectly regular and in accord with the magnetic records. The irregularities in quite small intervals of time amounted to 2·7 to 5·4 minutes. As at first it was thought that the deviations might be ascribed to the iron safety-lamp employed, a third observation was made in the morning, the lighting being effected by a stearine candle. The results were exactly the same as on the first day. As the observations were made at a comparatively large distance from other workings, and as the shaft was 200 yards away, it is evident that magnetic observations can, under such conditions, be only satisfactorily conducted during the night in the absence of the electric current.

Another source of error is the safety-lamp. Composed of various metals, the lamp in a hot condition sets up thermo-electric currents which act on the magnetic needle. In order to obtain information on this point, the author placed six mine-surveyor's safety-lamps, free from iron, one at a time, first in a cold condition, then heated, at the pole of a sensitive magnetometer. Of the six lamps examined, two, when cold, had no action on the needle, whilst all acted on it when hot. The deviations observed amounted to 30 to 160 seconds. A new benzine lamp, that had not previously been used, caused a deviation of as much as five minutes. The deviation increased with the temperature of the lamp. A quite new aluminium safety-lamp caused the same deviation when cold as when hot. From these results it follows that the mine - surveyor, before making magnetic observations with delicate instruments, should carefully test his lamp. The influence of slight magnetic properties may be lessened by holding the light in the prolongation of the magnetic axis. With side - lighting great care is necessary.

Illustrations have been published of the Bochum magnetic observatory[*] and of the Cseti mine theodolite,[†] an instrument specially adapted for rapid surveying, and for use in low workings and on steep inclines.

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[*] *Glückauf*, vol. xxxi. p. 1291.
[†] *Berg- und Hüttenmännische Zeitung*, vol. liv. p. 391.

IX.—COAL-WASHING.

Screening and Cleaning Coal.—Illustrations have recently appeared of the Francou coal-washer.* The machine is of the jig type, with a water-piston connected directly to a steam-piston placed above it. The steam-cylinder is single acting, steam being admitted on the up-stroke only by means of a slide valve worked by tappets on the piston rod. The upper part of the steam-cylinder is provided with adjustable air openings to regulate the speed of the stroke. The return or downward stroke is effected by gravity, any desired weight being placed on the piston. The washing compartment of the jig is much larger than the other. Its bottom is inclined towards a bucket elevator for removing dirt, and there is also a sliding door at the bottom. A bed of shale is used on the sieve, and the coal is discharged over the front. The stroke of the piston is three to four inches, according to the size of coal washed.

J. J. Ormsbee † desibes a coal-washing plant in the Southern United States.

F. Rochelt ‡ describes the Wunderlich coal-washing system as applied at Kladno. It depends on the rate of fall of bodies of different densities without shock in a steady stream of water. The author first considers the subject theoretically, and then proceeds to a description of the plant in use. The Kladno coal is very difficult to purify properly by washing, but this process is stated to give satisfactory results.

Coal-Screening by Electricity in Hungary.—The Hungarian technical journals § report that at the Sekul Colliery in South Hungary the coal-screening plant, which was formerly driven by a portable engine, is now driven by electricity. The primary motor for the plant is a 50 horse-power engine, placed in the engine-house of the winding and pumping shaft, and this serves also for driving an electro motor for an underground electric winding-engine. The dynamo for the coal-screening plant is connected to the engines by a length of 860 feet of 6-millimetre copper wire. The dynamo is a constant-current machine, giving a current of 500 volts and 67 amperes, equivalent to 27 horse-

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* *Revue Universelle des Mines*, vol. xxxi. pp. 166–179.

† *Colliery Engineer*, vol. xvi. pp. 27–29.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 79-83, and 93-97, four illustrations.

§ *Berg- und Hüttenmännische Zeitung*, vol. lv. p. 95.

power; motion is transmitted to the pulley of the separator by a belt. Four grades of coal are screened—cobbles No. 1 and No. 2, nuts, and dust. The No. 1 is separated by tipping the coal out of the trucks on to a screen, the bars of which are 2·4 inches apart, and the small coals passing through are collected in a hopper and conveyed by an elevator to the conical screening cylinder. This is some 16 feet in length, and 6 to 4½ feet in diameter, with circular perforations 0·79 inch in diameter, through which the small coal falls into a scoop, and thence into a truck. At the farther end of the first sieve, and mounted on the same axis, is a second screening drum 6 feet long and 3½ to 3 feet in diameter, the holes being 1½ inch across. The coals, of between 1½ inch and 2½ inches diameter, are delivered from the second drum and thrown on to an inclined plane for picking over, whereas the screenings of 0·7 inch to 1½ inch diameter fall on to a shoot and thence into the separating box, where they are washed. This box is made of stout sheet iron, and discharges the coal continually, the shale being discharged at intervals.

Manufacture of Briquette Fuel.—A mixture of Mexican asphalt, with peat or turf pressed together and baked, is said to have given good results as fuel.[*]

At the newly erected briquette factory in connection with the Fröhliche Morgensonne Colliery, near Wattenscheid, Westphalia, the slack is tipped into a storing tower, from which it is led by a creeper to the point where its mixture with ground pitch is effected. The mixture is then led by creeper and elevator to a distributing hopper, and then by travelling bands, charging elevator, and conveyors into two directly-fired heating ovens. After the mixture is thoroughly warmed, it is led by creepers to the Couffinhall presses, which produce briquettes weighing 3 and 5 kg. (6½ and 11 lbs.), the three presses turning out 175 tons of briquettes in a day of ten hours.[†]

Loading Coal.—Illustrations have been published [‡] of the appliances erected at Cleveland, America, for rapidly emptying full-sized railway trucks. In a recent test three trucks were discharged into a vessel's hold in three minutes. The apparatus consists of a cylinder 40 feet long, 11 feet internal and 16 feet external diameter. It is set 28 feet above the dock and level with the railway. The truck is run in

* *Engineering News*, New York, vol. xxxv. p. 128.

† *Engineering and Mining Journal*, vol. lxi. p. 186.

‡ *Iron Age*, vol. lvi. pp. 783–784; *Engineering and Mining Journal*, vol. lx. pp. 444–445.

from one side, clamped in place automatically, and then overturned side-ways by rolling the cylinder by means of a rope passing around it up an inclined plane. Exactitude of motion is ensured by pins on the truck fitting holes in the cylinder periphery. The rope is actuated by a steam-cylinder 30 inches in diameter and 19 feet stroke. The shoot which receives the coal is at first horizontal, and is afterwards lowered.

Transport of Coal.—Some remarkable views have recently been published to show the accumulation of coal-boats and barges on the Allegheny, Monongahela, and Ohio rivers in the Pittsburg district, due to the lack of water. In discussing the subject L. M. Haupt * states that no coal was shipped by river between April 18 and November 28, or over seven months. On 7th November 1895 it was estimated that there were no less than 1,200,000 tons of coal on 2500 vessels tied up in Pittsburg Harbour waiting for the river to rise sufficiently to enable them to be moved. Some dams have been made to hold up the water, but much more work is necessary.

Coal Storage.—An illustration has appeared † of the coal storage bins at Duluth, Minnesota. These are 900 feet long and 150 feet wide. Below them works a Jeffrey conveyor 950 feet long. This consists of discs clamped to an endless wire-rope, and working in a trough. Other descriptions of similar plants employing this conveyor for coal and ash have also appeared.‡

An illustration has recently appeared § of a circular bin erected at Astoria for holding coal in order to economise ground space. It is 28 feet in diameter, 54 feet in height, and has a capacity of 1000 tons. It is loaded by a jib crane and bucket, and discharged through a door near the base.

Burning Finely Divided Coal.—Illustrations have been published || of the Wegener system of firing boilers with finely divided coal. In the form now adopted, the powder is contained in a hopper with a sieve bottom, and drops into a vertical tube up which the air supply for the furnace passes. At the top this tube is bent so as to pass horizontally into the furnace. Air is drawn in by the natural draft of

* *Journal of the Franklin Institute*, vol. cxli. pp. 81-97, 171-182.
† *Iron Trade Review*, vol. xxix. No. 8, p. 11.
‡ *American Manufacturer*, vol. lviii. p. 228.
§ *Iron Age*, vol. lvii. p. 366.
|| *Colliery Guardian*, vol. lxxi. p. 163 ; *Engineer*, vol. lxxxi. p. 44 ; *Engineering*, vol. lxi. p. 80.

the chimney, and it drives a small fan like a smoke-jack placed at the bottom of the tube. This fan works a small hammer which knocks the sieve so as to cause the coal to fall through. The strength of the blow is regulated to control the amount of fuel used, and the air supply is varied by raising or lowering the bottom of the tube, which nearly touches the floor. Extra air is supplied through additional tubes for burning very bituminous coal.

C. Schneider * gives an historical account of the use of coal-dust as fuel for steam-boilers. After describing in detail the Wegener, Schwartzkopff, Friedeberg, Ruhl, and De Camp systems for burning coal-dust, he discusses the advantages and disadvantages of coal-dust fuel. The advantages are—most perfect utilisation of the fuel, complete smokelessness, small amount of manual labour required, favourable results from any kind of fuel that can be applied in the form of dust, adaptability of the system to any kind of requirements, preservation of the boiler, and rapid removal of the fire in case of danger. The disadvantages are—the grinding of coal into dust before it can be applied, the necessity of mechanical power, the deposit of ashes in the flues and tubes, and the dusty condition of the boiler-house which is caused in some cases.

In another memoir, C. Schneider † gives the results of experiments with the Schwartzkopff and Friedeberg methods of coal-dust firing.

B. Kosmann ‡ describes several mills for producing the coal-dust for firing furnaces. Illustrations are given of the Propfe mill and of the Friedeberg mill.

B. Kosmann § advocates the use of brown coal as fuel in briquette works, the coal for the purpose being reduced to a state of powder.

Powdered coal-firing is described by F. Bleichsteiner.‖ He points out that the furnace arrangements must be such that the entry of the air for the combustion must be entirely independent of that of the fuel. Each must be carefully regulated, and the air must be as hot as possible if very high temperatures are to be produced. Most systems are faulty in this direction. The author considers the question of the cost of this kind of firing, and describes its application on the Neumann system.

The question is further considered by F. Toldt.¶

* *Mittheilungen aus der Praxis des Dampfkessel- und Dampfmaschinen-Betriebes,* 1896, p. 336. Compare *Journal of the Iron and Steel Institute,* 1873, p. 91.

† *Zeitschrift des Vereines Deutscher Ingenieure,* vol. xl. pp. 432–436.

‡ *Glückauf,* vol. xxxii. pp. 200–203.

§ *Berg- und Hüttenmännische Zeitung,* vol. lv. pp. 45–47, 61–64.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliii. pp. 555–559, with sheet of illustrations.

¶ *Ibid.,* pp. 616–617.

PRODUCTION OF PIG IRON.

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CONTENTS.

I.—*BLAST-FURNACE PRACTICE.*

Modern Blast-Furnace Practice.—In his Presidential address to the Institution of Mechanical Engineers, E. Windsor Richards describes a number of works illustrating the present condition of blast-furnace practice. From his statements and descriptions, it will be seen that present British practice with ores containing 50 per cent. of iron averages 1000 tons of pig iron per week, with a strong tendency to increase. The coke consumption varies from 18½ cwt. to 20 cwt. per ton of pig iron. Labour cost, including everything in connection with the blast-furnaces, from unloading the ores to loading up the pig iron, but excluding establishment charges, is as low in one instance as 24d. per ton of pig, rising to 30d. for hæmatite iron, and to 36d. for Cleveland iron.

To the Cleveland district more than to any other must be given the credit of having greatly improved blast-furnace construction and practice; and it still maintains the leading position in this country in the production of all descriptions of iron and steel. The adoption of the system of heating the blast effected a saving of about 2½ cwts. of coke per ton of pig iron, above that obtained by cast-iron pipe-stoves, besides permitting a higher pressure of blast to be used, and thus increasing the output of the furnace; indeed, the invention of fire-brick stoves rendered possible the large productions of to-day. Last year's work of Messrs.

Cochrane's three furnaces shows highly interesting figures. With iron-stone from the Cleveland mines they made 123,594 tons of pig iron over the whole of 1895, being an average of 41,198 tons per furnace, or at the rate of 792 tons per furnace per week, with an expenditure of 21·12 cwts. of coke per ton of iron. The average temperature of the blast over the twelve months was 1490° Fahr. A good and fair example of the working of a Cleveland blast-furnace using native ironstone over the last twenty years is furnished by No. 8 furnace at Eston, which was put into blast in 1874, and blown out in 1894, having made from one lining 484,412 tons of pig iron. During that period the furnace was damped down thirteen weeks, in consequence of the Durham colliers' strike. The average output per annum was 24,000 tons. Formerly cast-iron pipes were used for heating the blast, but latterly Cowper stoves. During the last year of its working it made 26,168·14 tons of good grey iron, using 26,891·18 tons of coke, being an average of 500 tons of iron per week, and 20·55 cwts. of coke per ton of pig.

Furnaces erected at Eston in 1877 continue to produce a little under 1000 tons of Bessemer iron per week, using 50 per cent. ores. The best of these furnaces produced last year 50,800 tons of iron with 18·60 cwts. of Durham coke per ton of pig iron. These furnaces, without any arrangements for cooling the boshes, last about five years, and give about 250,000 tons of iron, and then require relining. With present engine-power the above quantity cannot be increased; it has therefore been decided to erect six vertical direct-acting high-pressure engines, as there is no water available for condensing; the air cylinders are 84 inches diameter and 5 feet stroke. These engines, of exceptional strength, are being constructed by Messrs. Tannett, Walker & Co., Leeds, and are to supply 25,000 cubic feet of air per minute, at from 8 to 10 lbs. pressure per square inch to each of three blast-furnaces. The boilers are of the Lancashire type, 30 feet long, and 8 feet diameter, with two flues 3 feet 3 inches diameter, having five cross Galloway tubes, and are to work at 80 lbs. pressure, so that greatly improved results in working are expected to follow shortly upon their completion.

At Jarrow-on-Tyne a blast furnace plant was constructed with all recent improvements, from which greatly improved results were expected. As these results were not at first realised, it is of value to ascertain the causes, in order to avoid similar failure in future. The furnace No. 5 is 75 feet high; bosh, 20 feet diameter, having several cooling plates; angle of bosh, 80°; hearth, 11 feet diameter; throat, 16 feet; bell, 11 feet; capacity of furnace, 14,150 cubic feet; eight gun-metal tuyeres,

5¼ inches diameter, placed 6 feet above the hearth level. Blast of 3¼ lbs. pressure per square inch, heated by four Cowper stoves, 73 feet high and 22 feet diameter, to a temperature of from 1400° to 1500° Fahr. Durham coke with 8 per cent. ash and 1 per cent. sulphur, 19½ cwts. per ton of Bessemer pig iron. Production, 1000 tons per week from Bilbao and African ores, averaging 50 per cent. of iron, increased to 1100 tons during the last few weeks. Limestone, 8 cwts. per ton of pig. One pair of compound condensing vertical blast-engines, high-pressure cylinder 54 inches diameter, low pressure cylinder, 72 inches diameter; air cylinders, 100 inches diameter; stroke, 5 feet, making 17 revolutions per minute for 1000 tons of iron per week.

From such an installation as this it would be expected that a large production would be readily obtained at a low cost; but the furnace worked with great irregularity, and was continually hanging and slipping. Increased blast-pressures were tried, and failed to produce any improved results. The cause was evidently traceable to the steep boshes. So unsatisfactory and costly was the working, that the furnace was blown out in June 1893, and the boshes were altered to 68°. Since this alteration the furnace has worked well and economically. The engineering portion of the whole plant is well carried out. For a furnace having such a large reserve of blast and heating power, an output of only 1100 tons per week cannot be considered a good return for the large amount of money expended.

A blast-furnace of peculiar internal form, designed by Howson and Hawdon, was described by Jeremiah Head. Of these furnaces five are now in operation at the works of Sir Bernhard Samuelson & Co., and they are now giving such satisfactory results, that a sixth is being prepared. Two of the furnaces were making Cleveland iron, and three hæmatite. No. 5 furnace with 18 feet bosh, 70° angle, 11 feet hearth, 84 feet high, had made during the previous ten weeks, with rubio ore containing 50 per cent. of iron, an average of 1053 tons per week of good grey Bessemer iron, with a consumption of 18·1 cwts. of coke per ton of ash. The blast is supplied by ordinary vertical compound condensing quick-running engines at about 4½ lbs. pressure per square inch, and is heated by Cowper stoves to 1400° or 1500° Fahr. By increasing the volume and maintaining the heat of the blast, W. Hawdon expects shortly to attain 1200 tons per week.

The Dowlais Cardiff new blast-furnace plant is remarkable for efficient and economical working. The two furnaces have 20 feet boshes, 10 feet hearths, are 75 feet high, and from Bilbao ores containing 50 per cent.

of iron, each furnace produces 1250 tons per week of good grey Bessemer iron with a little over 19 cwts. of coke per ton. The production can be readily increased, should the state of trade require it.

In the course of his address, the author gave complete details of the blast-furnaces at the Edgar-Thomson works, at the Duquesne works, at Esch in Luxemburg, at Uckange in Lorraine, at Ruhrort, at Krupp's works at Essen, at Hoesch's works near Dortmund, at Micheville, at Mont St. Martin, at Cockerill's works, and at the La Providence works. In the United States, at South Chicago, and at many other works, there are furnaces doing really marvellous work. A type of furnace which has worked most satisfactorily and economically at the Edgar-Thomson works (Carnegie's) is 90 feet high, 20 feet bosh, having an angle of 75°, throat 16 feet diameter, crucible 13 feet diameter, eight tuyeres placed 8 feet 6 inches above the level of the hearth, projecting 6 inches inside the lining, and having nozzles 8 inches diameter; Cowper firebrick stoves heating the blast to about 1200° Fahr. Each furnace is blown by two single vertical blast-engines, having steam-cylinders 40 inches diameter, and air cylinders 84 inches diameter, together supplying about 26,000 cubic feet of air per minute at 10 lbs. pressure. This furnace produces the extraordinary quantity of 11,000 tons of Bessemer pig iron per month when using Lake ores containing 62 per cent. of iron. On many days of twenty-four hours the output exceeds 400 tons, using the very small quantity of 1790 lbs. of Connellsville coke to 2240 lbs. of iron, the coke containing 11 to 12 per cent. of ash.

The desirability and economy of these large productions of iron are questioned by many engineers and managers, owing to the hitherto great wear and tear and speedy destruction of the brickwork forming the lining of the furnace. But these objections have latterly been to a great extent surmounted, and are now best answered by the results obtained from furnace I. at the Edgar-Thomson works. This furnace has been in blast for more than five years, and has made over 650,000 tons of iron, with an average coke consumption, including all stoppages through strikes and other causes, of 1889 lbs. per 2240 lbs. of iron.

Special means of preserving the bosh lines of the furnaces are adopted, and are highly effective; indeed, the success attained is due in a great measure to this plan, which greatly prolongs the life of the furnace. Cooling plates or flat water-boxes are placed in rows about 2 feet apart, from the top of the tuyeres up to the height of the top of the boshes; they are made of gun-metal, about 5 feet long, shaped to the curves of the furnace, and placed about 6 inches away from the inside line of the

bosh ; they are about 4 inches wide by 3 inches thick, and have water
running continuously through.   The two rows above the tuyeres, and
the second and third above these, are connected together to save water ;
and above them three rows of plates are connected together.   Before
being put into position the cooling plates are tested by hydraulic pres-
sure.   Should a plate leak at any time during working, it can be readily
withdrawn and another substituted.   The crucible below the tuyeres is
kept cool by a strong cast iron plate surrounding the furnace ; a coil of
1¼-inch pipe is cast therein, which serves for the circulation of water.

Another bold change has been made in the size of the bricks used in
the construction of the furnace.   Formerly, and as is the practice now
in other countries, a huge lump of clay was used, sometimes as large as
30 inches long, 15 inches wide, and 6 inches thick.   Such a mass it was
almost impossible to bake thoroughly to the core.   Of late years this
thickness has been reduced to 3 inches, with improved results ; but the
sizes now used in America have been reduced to 13½ inches long by
3 inches thick, and 9 inches by 3 inches to break joints, the whole
3 feet thickness of the furnace walls being made up of two 13½-inch and
one 9-inch brick.

In order to obtain a large output with economical results, American
practice adopts a large hearth and a comparatively small diameter of
bosh.   The latter gives as much iron as the larger bosh, and uses less
fuel per ton of iron by reason of the gases being distributed equally and
rapidly over all the ore, and not working in channels, as with a larger
bosh.   The quantity of iron produced depends on the power of the
furnace to burn fuel, and, in order to do this, a large hearth is necessary,
together with a large volume of high-pressure blast.   When these are
provided, the narrower the bosh the more oxygen is removed from the
ores by the gases and less by solid carbon, hence lower consumption.

The author's own practice tends to prove that a furnace rapidly driven
works with greater regularity and gives a more even quality of iron,
lower in silicon, than a furnace slowly driven.

Mr. Carnegie is so satisfied with the great economy of the results he
has already obtained that he is constructing four more furnaces, and in a
few weeks will have two of them in operation at his Duquesne works,
near Pittsburgh.   The following are the leading particulars of this
installation, which is to cost about 600,000 dollars :—Height of furnace,
100 feet ; bosh, 22 feet diameter ; angle of bosh, 74° ; crucible, 14½ feet
diameter ; throat, 17 feet ; bell, 12½ feet ; ten tuyeres, 8 inches diameter,
placed 9 feet 8 inches above the level of the hearth.   There are to be

five pairs of blast-engines, vertical compound condensing beam type, having high-pressure cylinder 40 inches diameter, and low-pressure cylinder 78 inches diameter, two air cylinders 76 inches diameter and 5 feet stroke ; the ordinary speed is to be 40 revolutions per minute, at which speed each pair of engines will deliver 25,000 cubic feet of air at 16 lbs. to 18 lbs. pressure per square inch ; the maximum speed will be 50 revolutions, and maximum pressure of air 25 lbs. A production of 500 tons in twenty-four hours is expected from each furnace, being at the rate of 180,000 tons per annum ; and if the lining endures only four years of such work, the satisfactory quantity of 700,000 tons will be obtained—a quantity which an English furnace would require fourteen years to produce.

At Esch, in the Grand Duchy of Luxemburg, there are four blast-furnaces in operation, making together about 800 tons of basic pig iron per day, which is sent by railway 120 to 150 miles to Westphalia at the low carriage rate of 8s. per ton. This blast-furnace plant of the Société de Luxembourgeois is considered the most important in that region ; for the last month the furnaces made their largest average of 202 tons per day, using Westphalian coke containing about 8 per cent of ash, and minette ironstone, the best in that district, with Greek manganiferous ore to reduce sulphur, and additions of basic slag to give phosphorus up to 2·2 per cent. A new furnace is being constructed, and will be put into operation this autumn ; the height is 82 feet, bosh 23 feet diameter, angle 73°, hearth 11½ feet, throat 15 feet. There is much dust in the furnaces, and it is supposed to lie on the boshes, forming a protection to the brickwork, and so water-cooling plates are said to be of no practical advantage. In order as much as possible to prevent the dust from passing into the stoves, there are six tubes of 8 feet 2 inches diameter and 66 feet high resting in a pan of water ; the dust, passing alternately up and down these tubes, has time to deposit itself in the water, and is scraped out without stopping the blast. Five Cowper stoves, 83 feet high and 23 feet diameter, heat the blast to 900° C. Seven tuyeres of 7 inches diameter are used. For these high stoves a powerful draught is absolutely necessary. The chimney is 270 feet high and 11½ feet diameter at the outlet. A horizontal compound condensing engine, making 24 strokes per minute, supplies 22,000 cubic feet of air at 7 lbs. pressure per square inch, with steam at 6½ atmospheres ; high-pressure cylinder 52 inches diameter, low-pressure 78 inches, air cylinders 100 inches diameter, stroke 5 feet 3 inches. They have never succeeded in getting these cylinders to work without cooling them with water. For the new fur-

nace a vertical compound condensing engine is being constructed at Bayenthal.

At Uckange, in Lorraine, on the Moselle, there is a smaller and well-arranged new plant of three furnaces, two in operation, each making about 123 tons per day. The furnaces use minette ironstone containing from 33 to 34 per cent. of iron, obtained from their mines, about two miles distant. A new furnace in course of construction and nearly completed is 65 feet high, bosh 19½ feet diameter, hearth 9 feet 9 inches, with four tuyeres of 7 inches diameter, and with four Cowper stoves 62 feet high, 21¼ feet diameter. Directly after leaving the furnace the gas is conveyed to a receiver of large diameter, the bottom part of which is tapered to receive a valve easily opened for discharging the dust thus collected. The gas is further passed through ascending and descending wrought iron tubes of considerable height and diameter, and by lowering its speed time is given for more dust to become deposited on the surface of the water receptacle below; the mud thus obtained can then be easily scraped out. By these means a large proportion of the dust is prevented from entering the stoves and boilers. There are three vertical compound blast-engines.

At Ruhrort the author found the largest German production; the output at two furnaces for the thirty-one days of the month of March was 16,800 tons from ores averaging 40 per cent. of iron. The furnace was said to be 88 feet high, but the usual height would probably be nearer 80 feet. Bosh 21½ feet diameter, angle 63°, protected by several water-blocks, hearth 12½ feet diameter. Tuyeres, eight of 7 inches diameter; nozzle pipes red-hot by daylight; pressure of blast ⅘ atmosphere. Four Cowper stoves 98 feet high and 26 feet diameter. The furnace was lined with carbon bricks up to the boshes only; the bricks are thus kept well below the region of carbonic acid gas, and so far are doing well. A Bayenthal compound condensing vertical blast-engine running at 45 revolutions per minute drove one blast-furnace. It was said that this engine could run well at 60 revolutions per minute; but with the complicated cut-off gear such a speed would soon necessitate considerable repairs. The air cylinders were 78 inches diameter with 6 feet stroke.

Another set of eight blast-furnaces in that district—seven in blast—producing together 25,000 tons per month of basic, foundry pig, and ferro-manganese containing up to 80 per cent. of manganese, while working fairly well, offered nothing especially favourable to record, except that, being fully alive to keep to the front, they have just erected and nearly completed the first of eight pairs of horizontal compound condensing blast-engines, having air cylinders 80 inches diameter, 5 feet stroke;

and while the manager expressed himself satisfied that 150 tons per day of basic iron is ample for a furnace, he is providing sufficient blast power to give 200 tons. The minette ironstone from Luxemburg costs 3s. 6d. per ton, and carriage 6s. 6d. This is mixed with Swedish Grängesberg ore, containing 60 per cent. of iron and 1 per cent. of phosphorus, costing 15s. 6d. f.o.b. at Ruhrort, and with puddlers' tap-cinder from England. The basic pig iron so produced, containing 0·5 per cent. of silicon and 2 per cent. of phosphorus, is conveyed to a 120-ton mixer, where the sulphur is reduced to a very low percentage by the addition of manganese. The whole of the 18,000 tons of steel produced monthly at these works is made by the dephosphorisation process; indeed, very little acid steel is now made in Germany, the former being preferred.

At Micheville two furnaces have recently been put in blast, which are excellent types of good construction. The following are details:— Height of furnaces, 80 feet; bosh, 22 feet diameter; angle, 72°; hearth, 10 feet diameter; throat, 16¼ feet. The charges are exceptionally heavy, consisting of coke 5½ tons and ironstone 15 tons. There are only four tuyeres at work, although provision is made for seven. The average production is nearly 150 tons per day.

The Société John Cockerill has constructed in the best possible manner, and just put into operation, a very fine blast-furnace installation, having all the most recent improvements. It is 78 feet high, bosh 20 feet diameter, angle 71½° There are five tiers of water-blocks above the tuyeres, to protect the lining of the boshes. The hearth is 10 feet diameter at the bottom, widening to 11 feet at the level of the tuyeres. Seven tuyeres of 5 inches diameter are placed 9 feet apart from nose to nose, and 6¼ feet high above the level of the hearth. The throat is 15 feet diameter, having two gas outlets to one large downcomer, which leads into a capacious receptacle containing water for cleaning the gases. Four Cowper stoves, lined with octagonal bricks, 82 feet high and 22 feet diameter, are used; the chimney, with wrought iron casing lined with bricks, is 230 feet high, with a clear outlet of 10 feet diameter.

One of the blast-engines is a copy of a type adopted at some American works. It has two outside flywheels, an arrangement which makes it difficult to reach readily some of the working parts. It is a single vertical quick-running engine, with air cylinder 84 inches diameter placed above the steam-cylinder, which is 42 inches diameter. The maximum steam pressure is six atmospheres, and the valve gear has somewhat complicated motions for early cut-off. The stroke is 5 feet, and the speed 40 revolutions per minute, with the intention of running up to 60;

if found desirable, the pressure of blast may be increased to one atmosphere. The company are constructing a second engine of better design, and of greater power and more strongly made, consisting of a pair of vertical compound condensing engines, with a single large flywheel in the centre of the shaft; high-pressure cylinder 30 inches, low-pressure 48 inches, two air-cylinders each 68 inches diameter; stroke 4 feet, to make from 40 to 60 revolutions per minute; and pressure of air from 7 lbs. to 10 lbs. per square inch.

Great attention has been given to the boilers; they are 9 feet 10 inches diameter, and have each three tubes; the two top tubes are 3 feet 3 inches diameter, and the bottom one 2 feet 8 inches; length, 32½ feet. The boilers are fired by the gas from the furnace; and each tube has a separate chamber of large capacity, to ensure complete combustion.

Westphalian coke is used. The ores are principally Tafna, rubio, and purple, all low in phosphorus for making Bessemer pig iron. From the ordinary furnaces about 100 tons are obtained daily, and from the new furnace much better results are expected, probably 200 tons a day.

Recent advances in blast-furnace practice in the Cleveland district are discussed by W. Hawdon.[*]

The Furnace Value of Iron Ores.—H. V. Tiberg [†] discusses the question of the furnace value of poor and of rich iron ores, the ores being otherwise similar. Practice and theory, he points out, do not always coincide. He considers the question theoretically, and also the results obtained in practice in Sweden, and he gives the following table :—

Furnace Yield of Ore.	One Ton of Pig Iron made requires		One Ton of Ore requires of Charcoal.
	Of Ore.	Of Charcoal.	
Per Cent.	Tons.	Hectolitres.	Hectolitres.
30 . . .	3·23	92·3	27·7
35 . . .	2·86	83·3	29·2
40 . . .	2·50	76·5	30·6
45 . . .	2·22	71·2	32·0
50 . . .	2·00	67·0	33·5
55 . . .	1·82	63·6	35·0
60 . . .	1·67	60·7	36·4
65 . . .	1·54	58·2	37·9
70 . . .	1·43	56·2	39·3

He considers the question mathematically, and discusses it generally.

* *Iron and Coal Trades Review*, vol. lii. pp. 157-158.

† *Vermländska bergsmannaföreningens Annaler; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. pp. 604-607.

The Manufacture of Charcoal Pig Iron Low in Phosphorus.

—H. Tholander * observes that at present pig iron low in phosphorus forms an important article of export from Sweden. To obtain a satis-factory price, the iron must not contain more than 0·025 per cent. of phosphorus. Still better prices can be obtained when the percentage of phosphorus is guaranteed not to exceed 0·020 per cent. In the making of very grey pig iron, all the phosphorus that is contained in the ore, limestone, and charcoal passes into the iron made. By careful analysis it is possible to calculate with a fair degree of accuracy how much phos-phorus will pass into the iron from the ore and the limestone. It is different, however, in the case of the charcoal, the percentage of phos-phorus in which is very variable. It differs with the neighbourhood from which it is obtained ; it is different in hard woods to what it is in soft woods, and different not only in the wood of different ages, but it varies according to whether the wood was or was not barked. It is not possible to keep all these numerous kinds of wood apart from each other, and to obtain a true average sample is quite impossible. As a general rule, it may be taken that the charcoal will cause an additional per-centage of 0·015 of its weight of phosphorus to pass into the pig iron. Assuming that it is desired to obtain a pig iron with not more than 0·020 per cent of phosphorus, it follows that from the ore and limestone taken together not more than 0·005 per cent. of phosphorus must pass into the iron. It is not, however, possible even to calculate on so low a percentage of phosphorus from the charcoal as 0·015. If it is a ques-tion of producing a pig iron particularly low in phosphorus, it is best to carefully sift the charcoal, and keep the smalls for other purposes, these smalls being relatively rich in pieces of bark, which, as is well known, is particularly rich in phosphorus. But even when using the same ore and the same charcoal, different results may be obtained by variations in the working of the furnace. A very grey pig iron made from the same ore charge by the use of 10 per cent. more charcoal may contain some 0·005 per cent. more phosphorus than the metal produced from the same ore charge with 10 per cent. less charcoal. The easier a charge melts the more readily can a pig iron low in phosphorus be produced, conse-quently a red hæmatite with 50 per cent. of iron and from 0·007 to 0·009 per cent. of phosphorus is relatively good for use in the manufacture of a grey pig iron low in phosphorus. Unfortunately these ores are rare, their usual percentage of phosphorus being from 0·018 to 0·030. Mag-netites, too, differ greatly in their furnace value for this purpose. Ores

* *Jernkontorets Annaler*, vol. I. pp. 163–168.

containing manganese differ in this way from those which contain none, and the reducibility and fusibility also differ with the structure and composition of the gangue. The basicity of the charge is also of importance. The percentage of charcoal used will increase with the percentage of the lime used for pig irons of the same percentage of carbon, and the more charcoal there is used, the higher will the percentage of phosphorus be that passes into the pig iron made. More limestone must not be used, therefore, than is necessary to keep the percentage of sulphur down within the desired limits. The preparation of a basic slag, by the addition of more limestone, is not particularly important, as when grey iron is being made, its power of absorbing phosphorus is not particularly large. If, however, the ore is self-fluxing and yields a basic slag, then the result is better, the slag retaining more phosphorus. As a general rule the furnace manager can do but very little to change the percentage of phosphorus in the pig iron if it is to be obtained from definite ore, and is to have a definite percentage of carbon. It is then rather just what the ore, limestone, and charcoal make it. The charcoal should, however, be kept well sheltered from the action of rain and snow, and should be thoroughly sifted before use, and the wood should have been barked before use for charcoal purposes. Very grey iron, as has been pointed out, may be higher in phosphorus than a similar iron less grey in character ; and when very white metal is being made, a considerable reduction in the phosphorus percentage may ensue ; but for such an iron there is no demand.

The Manufacture of High Silicon Iron.—According to J. S. Kennedy,* manganese acts in the blast-furnace as an aid to the manufacture of high silicon or soft irons. The author has made iron containing 4 to 5·5 per cent. of silicon with slag containing 30 to 31 per cent. of silica, but there was sufficient manganese in the ore mixture to ensure 2 to 2·3 per cent. in the metal. The highest silicon contents obtained by him was 8·753 per cent., and this was when the furnace was running on 3 per cent. silicon iron, and a series of mishaps disabled the blowing power. The iron contained only traces of manganese, and the slag was normally an acid one. The bottoms came up rapidly, and the iron was hot and thick.

The Reduction of Manganese in the Blast-Furnace.—In view of the importance of manganese in the iron industry, it is evident that

* *Engineering and Mining Journal*, vol. lxi. p. 42.

the metallurgist should know the conditions most likely to produce good metal, and be able to form an idea of the amount of manganese that will unite with the iron. It is, therefore, not sufficient to know the proportion of manganese contained in the ore. It is not always evident why a mixture of ores containing from 20 to 25 per cent. of manganese should produce iron with less manganese than others containing only 4 to 5 per cent., although the conditions may have been precisely the same. F. Büttgenbach * advocates the adoption of a modification of the Berthier dry assay, which gives a button of iron indicating whether the manganese will be reduced in the blast-furnace or not.

The Smelting of Titaniferous Ores.—A. J. Rossi † deals at considerable length with the question of the smelting of titaniferous ores in the blast-furnace, and describes an extensive experiment with these ores in a small furnace 30 feet high. The view is advanced, and strongly supported, that titanium oxide, under certain circumstances, may replace silica in the slag without affecting the working. The author refers to his previous paper on these ores, ‡ and also to the statements and experiments of others to show that titaniferous ores have been largely smelted in England, Sweden, and America, with successful results. Forbes, at Norton on the Tyne, used these ores in the blast-furnace with large additions of silica, so as to produce a slag approximating in composition to sphene or titanite, containing about 35 per cent. of titanium oxide, 25 to 33 of lime, and 28 to 35 of silica. These additions, however, tax the productive power of the furnace, and the author's experiments have shown that they are unnecessary. Titano-silicates, or, in fact, practically titanates, are fusible when the basic elements are alumina, lime, and magnesia. The slags are more fusible when the oxygen ratio of acids to bases does not exceed 4 to 3, but outside these limits the slag is still fusible like silica slag, although the fusibility decreases more rapidly than in the corresponding silicates when the proportion of bases is increased. Thus comparatively less fluxes are required when titanium is present in place of silica. As the ores and extraneous matters contain alumina, it is only necessary to add magnesia, which may be done in the form of dolomite. The author then shows the saving in the amount of slag that Forbes could have made with

* *Revue Universelle des Mines,* vol. xxxii. pp. 53–61.

† *Iron Age,* vol. lvii. pp. 354–356, 464–469.

‡ *Journal of the Iron and Steel Institute,* 1893, No. I., p. 298.

this method. As examples of fusible compounds the following are quoted :—

SiO₂	.	.	.	.	11·94	14·82	16·00	15·60	18·00
TiO₂	.	.	.	.	38·20	32·90	28·48	40·50	34·50
CaO	.	.	.	.	23·40	21·02	26·00	21·00	27·60
MgO	.	.	.	.	6·50	9·50	10·00	8·00	10·00
Al₂O₃	.	.	.	.	15·00	10·45	12·00	10·00	12·70
FeO	.	.	.	.	5·00	4·50	6·50	2·00	...
Oxygen ratio	.	.	.	4 to 3·1	4 to 3	4 to 2·3	4 to 2·5	4 to 3

Experiments are quoted to show that fusibility depends on the oxygen ratio, and that titanic acid, even without silica, does not cause infusibility if the proper bases are present.

The blast-furnace experiments on a large scale were made by the author during last summer. The furnace was of about three tons daily capacity, with an open top. At first Lake Superior hæmatites containing no titanium were used for comparative purposes, and subsequently titaniferous ore from Essex county in the Adirondacks was smelted. Full analyses of the various ores, coke, and fluxes used are given, those of the titaniferous ores being as follows :—

				Millpond.			Sanford.				Cheney.	
SiO₂	.	.	.	1·09	3·67	1·53	0·87	2·46	1·39	1·34	...	9·79
TiO₂	.	.	.	10·73	13·38	19·74	10·91	20·03	19·52	18·70	8·25	15·77
Al₂O₃	.	.	.	0·44	1·50	3·50	0·53	3·50	4·00	...	...	7·12
CaO	.	.	.	traces	little	little	...	...	...	...	...	8·89
MgO	.	.	.	traces	0·50	1·60	...	...	...	...	...	3·00
Mn₃O₄	.	.	.	0·13	...	...	...	...	...	...	...	...
Fe₃O₄	.	.	.	87·20	82·37	73·62	87·60	70·73	70·80	71·03	86·53	55·64
P	.	.	.	none	0·017	0·37	none	...	0·022	...	0·74	1·00
S	.	.	.	none	0·068	0·08	none	...	0·028	...	0·30	...
Fe	.	.	.	63·45	59·56	53·62	62·65	51·22	51·30	51·44	62·15	40·33

Illustrations are given of the furnace, which is 20 feet high from the bottom of the hearth to the charging platform; the crucible is 2½ feet in diameter and 2¼ feet in height, the boshes are 3 feet high and 4½ feet in diameter, and the stack tapers to a diameter of 3 feet at its top, a height of 14¾ feet above the boshes. The capacity is thus nearly 200 cubic feet. An iron pipe stove is used, giving blast not over 400° F. There are three tuyeres with wrought iron cooling coils, and a water-sprayed iron casing surrounded the boshes. The blast usually amounted to 350 to 400 cubic feet per minute, at a pressure of 1 to 1¼ lb. The best results were obtained by fast driving. In no case did the slags contain much iron. They melted well, but the temperature was not sufficient to reduce silica. The iron was invariably white.

After a run with ordinary ores to test the capability of the furnace, the burden was gradually changed to the titaniferous ores. The mixture then averaged 55 to 56 per cent. of iron, and the best production in twenty-four hours was 5035 lbs. It was found that the yield increased as these ores appeared to be reduced faster. When fully on titaniferous ores the mixture contained 52 per cent. of iron, and the best run was 6735 lbs. in the day. The slags at the beginning, middle, and end of this run on mixed ores averaged as follows :—

SiO_2	.	.	.	.	.	34·10	29·50	27·29
TiO_2	.	.	.	.	.	4·90	9·96	17·48
Al_2O_3	.	.	.	.	.	22·00	18·26	14·43
CaO	.	.	.	.	.	23·63	24·12	22·71
MgO	.	.	.	.	.	10·00	9·72	11·55
FeO	.	.	.	.	.	3·82	6·40	4·30
Oxygen ratio	.	.	.	.	4 to 4·4	4 to 4·1	4 to 3·5

When running on titaniferous ores without hæmatite, typical analyses of slag were as follows :—

SiO_2	.	.	.	.	20·59	15·32	14·82	15·90
TiO_2	.	.	.	.	26·81	31·26	31·97	34·38
Al_2O_3	.	.	.	.	10·17	14·50	12·43	11·23
CaO	.	.	.	.	23·60	20·56	24·00	22·10
MgO	.	.	.	.	10·24	9·09	9·97	9·70
FeO	.	.	.	.	6·90	6·02	4·50	6·40

In the three runs with hæmatite, mixed ores, and titaniferous ores alone, the following details of the consumption are given, together with the average iron contents :—

Pig iron	.	.	.	.	.	1·00	1·00	1·00
Limestone	.	.	.	.	1·15	1·19	0·95
Coke	.	.	.	.	2·15	2·20	1·99
Iron content of ore per cent.	.	62	56	52

In the third run the average percentage of the titanic acid was 20 per cent., and it is seen that the fuel consumption is less, although the iron content was lower. The amount of fuel per ton of iron is, of course, high, but it must be remembered that the furnace was small and open-topped, and that the blast was only heated to 400° F. When blowing out, the furnace was easily emptied to within a foot of the tuyeres, and no cyanonitride of titanium was visible. The lining was cut in some places and well lined with protective glaze, but there was no building up.

The slags ran freely over a runner 40 feet long, and caused no trouble. With titaniferous ores, the percentage of ferrous oxide in the slags was determined by ordinary methods, but the titanium interferes with it

and is difficult to eliminate, so that the result may be too high by 2 or 3 per cent., but for comparative purposes this was neglected.

In the working of the furnace, metal was cast twice every twenty-four hours, and cinder was tapped every hour or so, and there was no reason why the furnace should not have run for an indefinite period.

The iron made contained none, or only small percentages of titanium. It is white, with a close fine grain, and is remarkably tough and hard. Its transverse breaking strength is 2700 to 2900 lbs. on an inch square bar supported on centres 12 inches apart, and it chills to a remarkable depth.   It is pointed out that titaniferous ores are almost always of Bessemer quality, and the evidence afforded by these experiments, and by furnaces regularly using ores containing a small proportion of the element titanium, show that highly titaniferous ores can and will be used with advantage and success.

A. J. Rossi * gives the result of four crucible experiments to determine the effect of additions of titaniferous to phosphoric iron ores in the blast-furnace.   Titaniferous ores are almost invariably Bessemer ores, and give a tough, hard, white, or steel-grey metal, with much combined carbon and low graphitic carbon.   It was to determine if these properties might not counteract the effect of phosphorus that the experiments were made. The buttons of metal obtained showed on analysis :—

	I.	II.	II.	IV.
Graphitic carbon . . .	2·99	3·54	...	3·98
Combined carbon . . .	0·18	0·33	...	little
Total carbon	3·17	3·87	...	...
Phosphorus . ·. . .	1·125	1·229	2·862	3·229
Titanium	...	0·35	...	0·47

In the first and third experiments no titanium ore was used, and the metal was such as might be expected, but in the second and fourth the resulting metal was harder and stronger with nearly all the carbon in the graphitic state.

The Lighting of Blast-Furnaces.—F. Bicheroux † describes the old method of lighting up blast-furnaces, in which an iron platform is built, and the new method in which recourse is had to a pile of logs resting on wooden supports.

* *Transactions of the American Institute of Mining Engineers,* Pittsburgh Meeting, 1896.   Advance proof.

† *Revue Universelle des Mines,* vol. xxxiii. pp. 175–231, with plate.

Blast-Furnace Tuyeres.—F. Büttgenbach * criticises the various forms of blast-furnace tuyeres in use, and gives drawings of a new form of fireclay tuyere without cooling.

Cooling Appliances for Blast-Furnaces. — F. Büttgenbach † observes that the best protection for the melting zone of the blast-furnace consists in keeping this portion of the furnace, from the boshes downwards, well cooled by the aid of water. He describes how this may be done, giving the preference to flat weldless boxes of sheet-iron which are let into the brickwork of the furnace. They are built in such a manner that a portion projects outwards beyond the brickwork of the furnace, and remaining open, enables any slag accretions to be removed with considerable facility. These boxes only require about a sixth or an eighth of the quantity of water that is necessary when water-cooled tuyeres are used for this purpose. The author considers that it would be preferable to replace the expensive wrought iron boxes by others of cast iron in which Mannesmann tubes had been cast.

Bells for Blast-Furnaces.—To afford relief for a sudden upward rush of gas in furnaces using fine ore, G. H. Raney and M. H. Thompson ‡ have designed a bell which has a cylindrical extension at its apex, provided with an outwardly opening valve. This is placed at some height above the cone, so that it cannot be covered by the charge.

Carbon Bricks in the Blast-Furnace.—R. W. Raymond § states, on the authority of Professor H. Hoefer of Leoben, that at the Donawitz furnace, the carbon bricks lining the hearth were laid on a strong iron mantle. The thickness was one metre in two interlocking layers of 600 by 400 millimetres. The mortar consisted of three parts of coke to one of clay. Before blowing in, the carbon bricks were protected by a 150 millimetre layer of chamotte bricks, of which the bottom was also made. The furnace has now run four years, with an average annual out-turn of 55,000 tons, and the carbon bricks are still 700 millimetres long. At the Edgar-Thomson furnaces, according to J. Gayley, there is one furnace which was blown-in in 1893 with carbon bricks in the bosh

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* *Berg- und Hüttenmännische Zeitung*, vol. liv. pp. 347–349.

† *Ibid.*, vol. lv. pp. 415–417.

‡ *Iron Age*, vol. lvi. p. 1158, with illustration; *Iron Trade Review*, vol. xxviii. No. 47, p. 11.

§ *Transactions of the American Institute of Mining Engineers*, Pittsburgh Meeting, 1896. Advance proof.

wall, but their value cannot be determined until the blast is ended. In the meantime no further use is being made of these bricks.

In Belgium the La Providence Company has decided, according to J. Smeysters,* to substitute for the Marchin conglomerate and refractory materials hitherto employed, the graphite bricks successfully used in German blast-furnaces producing pig iron. Composed of powdered graphite agglomerated with the aid of a small quantity of tar under great pressure, these bricks have the following composition :—

Carbon.	Silica.	Ferric Oxide, Alumina.	Total.
92·50	3·60	3·35	99·45

This is the first application of these bricks in Belgium.

Dynamite in Blast-Furnace Practice.—J. S. Kennedy † gives some notes on the use of dynamite in blast-furnace practice. It is used for breaking down accumulations or scaffolds by making an opening in the bosh, drilling a hole and inserting a cartridge. It is also employed in opening a chilled tap-hole. In this case care should be used to put the hole as far inside the jambs as possible, and the cartridge should not be exploded until a considerable body of iron and slag has accumulated in the hearth, so as to wash out the hole well on casting. The explosive may be safely used even in red-hot material by placing it in a pipe considerably smaller than the bore-hole, so that it can quickly be introduced. Dynamite is also useful for removing tuyere-breasts and cinder-coolers, and also in removing lip-rings which have burned past to the hopper. The author also describes how he used dynamite for loosening a bridge in a furnace which had been banked with indifferent coke and stopped down for eleven weeks. Clinkered coke and ashes were removed through the tuyere openings and slag notch from that point to the arch two or three feet above the tuyeres. One cartridge and then another was exploded, and then two together just under the arch, and this brought it down and filled the hearth with material which contained a considerable proportion of red-hot coke. Blast was then turned on, and three hours afterwards slag was tapped off.

Stopping the Tap-Hole.—The appliance devised by S. W. Vaughen for stopping the tap-holes of blast-furnaces without cutting off the blast has recently been illustrated.‡ It is mounted on a crane, so that it can

* *Annales des Mines de Belgique*, vol. i. pp. 95-97.
† *Iron Trade Review*, vol. xxix. No. 7, p. 11.
‡ *Iron Age*, vol. lvi. p. 1045 ; *Industries and Iron*, vol. xix. p. 450.

be swung into position against the hole. It consists of a cylinder filled with clay which is expelled by a piston pushed forward by a hydraulic cylinder attached behind. The supply of water is controlled by a hand-valve, so that the clay can be driven into the hole at any desired rate. The whole operation only requires a few seconds, and the apparatus is stated to be in successful use in several instances.

The Economical Use of Blast-Furnace Gases.—A. S. Keith [*] describes an arrangement designed and patented by John Tate of Workington, for heating the air, for combustion of gases, by a series of regenerative chambers in the boiler-seatings. Apart from the heat gained, there is the knowledge that during the variation in volume of gas (from the blast-furnace) there can be no cold air rushing through the flues. According to tests made by J. Crum, the increase was found to be 420° F. imparted to the air by these regenerators. On another occasion W. Crooke tested and found these regenerators supplying air at a temperature of 735° F. This arrangement will be especially appreciated by those using furnace gas, and it has been found that no matter, under nominal conditions, how poor the gas may be, ample steam can be maintained without coal-firing. The system is in successful operation in some six works in this country.

Hot-Blast Stoves.—M. Boecker [†] describes the brick stoves erected two years ago at the Tarnowski works at Stomporkow, near Neiclan, in Russian Poland. The author considers these as being probably the smallest Cowper stoves yet erected. Each stove has a diameter of 13 feet, a maximum height of 46 feet, and a total heating surface of about 35,060 cubic feet. Three such stoves serve to heat the blast for two coke blast-furnaces, each of which has a capacity of 2470 cubic feet, and produces daily 40 tons of grey and white forge pig iron, with a consumption of 0·95 ton of coke per ton of pig iron made. The blast attains a temperature of 600° C.; but a fourth stove is in course of erection, with a view to increase the temperature to 700°. The author states that 50 per cent. of the coke used comes from Upper Silesia, and that this has then become still smaller in size by transport and by transfer at the frontier. The charge, too, only yields 34 per cent. of pig iron. It must be admitted, then, the author observes, that the result attained is very satisfactory, especially as there are only 40 cubic

metres of heating surface for each ton of pig iron made. Until June 1894 only one blast-furnace had been at work. This was driven in connection with two of these small hot-blast stoves, the third stove being added when the second furnace was put into blast. For more than two years the furnace was at work without the least interruption.

F. Toldt * draws attention to fire-brick stoves for small blast-furnaces, which appear to be but little known. In 1884 hot-blast stoves were erected at Neuberg, in Styria, and were put in work during the same year. They were on the Massicks-Crookes system, which was described at the Vienna meeting of the Iron and Steel Institute in 1882. The internal diameter of these stoves was 9 feet 4 inches, and their total height was 62 feet 4 inches. Each stove had a total heating surface of 6459 square feet. There were four such stoves serving two blast-furnaces. These furnaces smelted a spathic ore from Altenberg, which in its calcined condition contained 50 per cent. of iron. The blast had a temperature of 600° C., and each furnace produced 20 tons of Bessemer pig iron in the day of twenty-four hours. The plant worked exceptionally well, and the stoves rarely required cleaning. The furnaces used charcoal as fuel. They have now been long out of blast.

Illustrations are published † of the hot-blast stove and bricks for use in it, as devised by J. Kennedy. The stove is a two-pass one, with a central vertical combustion chamber, $5\frac{1}{2}$ feet in diameter, lined with one ring of $4\frac{1}{2}$ inch, and one of $13\frac{1}{2}$ inch fire-bricks. The second pass consists of the remaining annular part, which is lined with special bricks. These are hollow and four-sided in shape, with two sides formed as curves struck from the centre of the stove, and the other two sides radial, so that they can be built in to form a cellular structure.

Illustrations have been published ‡ of the brick devised by F. C. Roberts for filling Cowper stoves, and also of the form of stoves adopted. The brick is of T form, or a rectangular brick with the corners removed, so that they interlock. They are made three inches in thickness and nine inches deep, and leave passages nine inches square. The heating surface in a stove 16 by 70 feet is given as 16,900 square feet.

Blowing - Engines.—An illustration is published § of one of a number of blowing-engines being constructed for the Carnegie Steel

* *Stahl und Eisen*, vol. xvi. p. 22.
† *Engineering News*, New York, vol. xxxv. p. 230.
‡ *Iron Age*, vol. lvii. p. 139.
§ *Ibid.*, pp. 412–413; *American Manufacturer*, vol. lviii. p. 187; *Engineering News*, vol. xxxv. p. 102.

Company. The engine is of the vertical compound beam type, with one low-pressure steam-cylinder of 78 inches, one high-pressure cylinder of 40 inches, and two 76-inch air cylinders. The stroke of all cylinders is 60 inches. Reynold-Corliss valve gear is used. The air inlet valves are of the Corliss type, actuated positively, and the delivery valves open automatically and are closed positively. The engine weighs 600,000 lbs. and the fly-wheel 100,000 lbs. Steam at 90 to 125 lbs. pressure is used, and the number of revolutions is to be a maximum of 50 per minute.

A New Charcoal Blast-Furnace Plant.—Illustrations of a new blast-furnace plant for using charcoal have been published.* It is situated at Gladstone, on the shores of Lake Michigan. Construction began in May last year, and the furnace was completed by January. The furnace is 60 feet in height, with 12-foot boshes, 7-foot hearth, and 5-foot bell. It has five tuyeres and five rows of bronze bosh plates. The hearth jacket is of 1-inch steel plates, cooled externally by water spray. The bell has a straight line motion attached, and is worked by a steam-cylinder through a lever. The downcomer is widened out at its lower end, where it passes into the dust-catcher. There are two 16 by 70 foot Cowper stoves, lined with Roberts bricks. Space is left for a third stove. Each stove has a heating surface of 16,900 square feet. Four boilers and two blowing-engines are provided. All buildings are enclosed and connected by covered ways on account of the severe weather in winter. The casting-house is a steel structure 50 by 115 feet, provided with sliding openings. The charcoal plant is also described.

Blast-Furnace Out-turns.—In an editorial article *Stahl und Eisen* † observes that it has been informed that each of the new blast-furnaces at the Edgar-Thomson Steelworks at Pittsburgh now produces 3000 tons of pig iron a week, or 428 tons in the twenty-four hours—an almost fabulous out-turn. In 1851 a furnace built at Borbeck, in Essen, was of the then largest size, producing 30 tons a day, as compared with a daily production of 9 tons in the case of the Siegen charcoal furnaces. Even in 1875 the daily out-turn of the Siegen blast-furnaces varied from 20 to 30, and did not in any case exceed 50. In 1890, in Westphalia, at Hörde, a daily out-turn of from 100 to 130 tons was about the maximum out-turn of a blast-furnace at that period. Now the new furnaces of the Rhenish-Westphalia district yield from 100 to 180 tons a day. Thus,

* *Iron Trade Review,* vol. xxix. No. I., pp. 32–36.
† Vol. xv. pp. 1045–1049.

since 1850, there has been a very rapidly rising out-turn. The furnaces, too, have increased proportionately in size, as is shown in tabular form.

Blast-Furnace Practice in Germany.—In January 1895 * the north-western section of the Verein Deutscher Eisen und Stahl Industrieller presented a memorial to the German Government praying for a lowering of the charges made for the transport of iron ores over long distances. In this it is pointed out that while ten years ago the cost of tap cinder was from 5s. to 6s. a ton, the price has now risen to 16s., the cinder containing from 54 to 56 per cent. of iron, and about 4 per cent. of phosphorus. This cinder is no longer obtainable to an adequate extent. Bog iron ores are now largely employed. These are obtained partly from Northern Westphalia and partly from Holland and Belgium. They contain up to $1\frac{1}{4}$ per cent. or more of phosphorus. They contain, however, much water, are very variable in composition, and difficult to smelt. It is a matter of much difficulty to obtain a pig iron of constant composition from them even with the greatest care, and this leads to increasing difficulty if it is desired to further treat direct the molten metal in adjacent steelworks. These bog iron ores are specially useful as an addition to Swedish ore too low in phosphorus for use by themselves. The Grängesberg ores contain about 60 per cent. of iron and up to 1 per cent. of phosphorus. The Gellivara ores vary in composition, from 65 to 69 per cent. of iron, and from 0·1 to 1·0 per cent. of phosphorus. Both these ores are difficult to smelt, and cannot be allowed to form more than one-third of the ore charge, as otherwise the percentage of phosphorus in the resulting pig iron would be too low.

The lowest percentage of phosphorus in basic Bessemer pig iron is now about 1·8; formerly 2·5 per cent. was considered a minimum. There is no other possible way of replacing the failing tap cinder, the memorialists show, than by using the minette ores of the Lorraine ore district, and the present transport charges are too high.

An investigation followed this memorial, and the official report states that the books of one works near the Rhine shows the cost of the ton of tap cinder in 1891 to have been 10s. 6½d., and in 1895 16s. 1d. Bog iron ores, too, are no longer able to supply its place, having been largely worked out. It is shown how greatly the cost has increased in recent years by comparing the cost of furnace-working as is made evident by the mixtures in use on the Ruhr a few years ago and those which are customary now. Then the furnace cost was the same

* *Stahl und Eisen*, vol. xv. pp. 960–967.

for a charge yielding 50·77 per cent. of iron as it now is for one from which only 39 per cent. yield is obtainable.

The following are balance-sheets of blast-furnace charges from West German ironworks :—

Description.	Price per Ton.	Yield.	Contents.		Charge.	Quantity Charged per Ton of Iron.
			P.	Mn.		
	Shillings.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Ton.
1. Tap cinder . . .	16·00	60·00	3·75	4·00	10	0·223
2. Bog iron ore . . .	9·50	39·31	1·00	0·00	10	0·223
3. Roasted spathic ore . .	13·50	48·00	0·02	8·50	10	0·223
4. Brown iron ore . . .	12·50	42·00	0·40	10·00	15	0·335
5. Minette, 40 per cent. iron .	9·40	36·00	0·63	0·24	10	0·223
6. Minette, 36 per cent. iron .	8·56	31·90	0·62	0·24	25	0·558
7. Swedish ores . . .	15·50	61·00	1·10	0·31	20	0·446

The costs were as follows :—

Description.	Cost of Ore.	Furnace Charges.	Cost of Limestone.	Phosphorus in the Iron.	Manganese in the Iron.
	Shillings.	Shillings.	Shillings.	Per Cent.	Per Cent.
1. Tap cinder . . .	3·57	1·89	0·28	0·836	0·45
2. Bog iron ore . . .	2·12	1·45	0·28	0·223	0·00
3. Roasted spathic ore .	3·01	1·52	0·23	0·004	0·94
4. Brown iron ore . .	4·18	2·32	0·44	0·134	1·67
5. Minette, 40 per cent. iron	2·10	1·12	0·04	0·138	0·02
6. Minette, 36 per cent. iron	4·78	2·49	0·11	0·346	0·07
7. Swedish ores . . .	6·91	3·76	0·17	0·490	0·07
Totals . .	26·67	14·55	1·55*	2·171	3·22†

The ores referred to in the above tables have the following compositions :—

Description.	Moist, as Charged.			Dried at 100° C.		
	Iron.	Manganese.	Phosphorus.	Iron.	Manganese.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Tap cinder . .	56·00	0·50	4·00	56·00	0·50	4·00
Bog iron ore . .	38·25	0·00	1·06	45·00	0·00	1·25
Roasted spathic ore	43·68	8·65	0·00	48·00	9·50	0·00
Brown iron ore .	39·87	4·05	0·11	44·30	4·50	0·12
Minette, 40 per cent.	36·00	0·18	0·67	40·00	0·20	0·75
Minette, 36 per cent.	32·04	0·27	0·67	36·00	0·30	0·75
Swedish ore . .	60·00	0·00	1·00	60·00	0·00	1·00

* 1·33 in original.   † 3·23 in original.

Most of the manganese in the tap cinder passes into the slag ; some of the minette ore is blown out of the furnace, the blast being at a higher pressure than is customary in Luxemburg and Lorraine. Subject to these exceptions, it is estimated that with good furnace-working, almost all the phosphorus and half the manganese passes into the iron. A furnace charge such as that just described would yield in practice about 43·082 of iron, 0·776 of manganese, and 0·948 of phosphorus, for every 100 of ore, or, leaving carbon and silicon out of calculation, a pig iron containing 1·73 per cent. of manganese and 2·11 of phosphorus. A calcareous slag must be made, and the furnace must work well if these results are to be obtained. The Swedish ore referred to was from Grängesberg, and the brown iron ore from Rossbach. The calculation above given was one presented to the German Government with a view to obtaining a reduction in the charges for the transport of iron ore over long distances. It was subsequently submitted to recalculation. The total charges amounted to 42s. 6½d. per ton, and the yield to 44·80 per cent. Other similar balance-sheets are also shown.

Official statistics collected in Germany show that charges smelted contained the following quantities of slag : *—

District.	Tap Cinder.	Basic Slag.	Scale and other Slags and Cinders.
	Per Cent.	Per Cent.	Per Cent.
On the Ruhr (two works) . . .	17–37	nil	10·9–25
In Lorraine (one works) . . .	nil	nil	5
In Luxemburg (two works) . . .	nil	2·87	nil
On the Saar (one works) . . .	2–3	2·70	18·8–19·8
Two other works on the Saar . .	5·5–7·3	nil	3·7–9·6

A. Gouvy † deals further with the progress of the manufacture of pig iron in Germany since 1882, with reference to the contributions by Boecker on the progress in Upper Silesia, by Schilling on Bessemer and basic pig iron, by Weinlig on forge pig iron and spiegeleisen, and by Müller on foundry pig iron.

Blast-Furnace Practice in Ontario.—On the last day of last year the blast-furnace at Hamilton, Ontario, was blown in. Prior to that date, the quantity of iron made in the district was small, and was derived at intermittent periods from small charcoal furnaces. The

* *Stahl und Eisen*, vol. xvi. p. 28.
† *Bulletin de la Société de l'Industrie Minérale*, vol. ix. pp. 457 and 815.

Hamilton furnace is 75 feet high, with 16-foot boshes, and its capacity is 150 tons daily. At present it is to be worked to two-thirds of its capacity. Ore from the Malone district is to be used. A steelworks is to be in operation next year. There are three firebrick stoves, 19 by 60 feet; a pair of cross compound blowing-engines of 1200 horse-power each ; and twelve boilers, 5 by 24 feet.*

A sketch of the early history of the iron industry in Ontario has recently been published,† in connection with the blast-furnace blown in at Hamilton on December 31. As early as 1800 a furnace was built at Lyndhurst, but only ran two years, although an adjacent forge ran for ten years longer. About 1815 a furnace was built at Normandale, on Lake Erie, and was run with charcoal successfully from 1823. In 1830 it was rebuilt on a larger scale, and finally shut down in 1847 owing to scarcity of ore and fuel. Nearly all the iron was sold as castings. The Marmora works in Hastings County was also started in 1820, and worked with various vicissitudes until 1847, when the owner of the previously mentioned furnace took them over, but the competition of canals caused work to be ceased in the following year, though the works and furnaces carried on a lingering existence until 1883. Three or four other furnaces were also built at intervals in different parts of the province, but only ran for short intervals. Failure is chiefly traceable to lack of experience and capital, and to the cost of transport.

The Pig Iron Industry of the United States.—J. Birkinbine ‡ gives a retrospect of the last forty years of the iron industry in connection with the fourth decade of the *Iron Age*. In 1855 most of the furnaces used charcoal, and cold-blast and bituminous coal did not outrank charcoal until 1869. Furnaces 45 to 60 feet high and 12 to 14 feet in diameter, with a daily out-turn of 25 tons, were large furnaces at that time. During the first half of this period advance was restricted to replacing the old solid structures by circular brick structures banded by iron. At first brick supports and then cast iron columns were used, with plate-iron shells. This permitted greater height and larger boshes as blowing machinery improved. The forehearth and tymp were replaced by water-cooled nozzles. The tops were closed and better stoves introduced. Then more attention was paid to the selection of materials, and the chemist grew into favour, so that now the ton of pig iron is

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* *Iron Age*, vol. lvii. p. 140 ; *Engineering and Mining Journal*, vol. lxi. p. 36.
† *Iron Age*, vol. lvii. pp. 240–241.
‡ *Ibid.*, vol. lvii. pp. 21–24.

produced from only three or four tons of raw material, instead of five
tons as in 1855, whilst the furnaces produce ten times as much iron.
As an example of the progress of the last twenty years, the Warwick
furnace at Pottstown may be quoted.   Built in 1875–76, the best week's
work before 1878 was 189½ tons.   The second campaign of 105 weeks
increased the figure to 356·2 tons, with a consumption of 1·2875 ton of
coal, 0·6875 ton of limestone, and ore containing 45·8 per cent. of iron.
In the five years from December 1880 the weekly product was 516·5 tons,
with an average consumption of 2920 lbs. of fuel (usually three-fourths
anthracite and one-fourth coke), 0·804 ton of limestone and ores con-
taining 50·5 per cent. of iron.   After another run, the furnace was
rebuilt 70 feet in height, and from 1889 the week's out-turn was 743
tons, the fuel consumption ranging from 2451 to 2720 lbs.   The addition
of firebrick stoves, bosh-cooling plates, &c., in 1892, reduced the fuel to
2250 to 2327 lbs. per ton, with ores averaging 61 to 63 per cent. of iron.
The weekly product was also raised to 976 tons, and now, during the
year 1895, over 1100 tons per week have been repeatedly produced.

The author then traces the costs of manufacture, and shows in a
general way the effect of larger stacks, improved coal consumption, and
richer ores, and also of the varying prices of the raw material.   There is
also given the following table, showing the size and production of the
Edgar-Thomson furnaces :—

Name of Stack.	Height, Feet.	Diameter of Bosh, Feet.	Date of Construction.	Total Output to end of 1894, Tons.
A . . .	65	15	1879	...
B . . .	80	18	1880	740,923
C . . .	80	20	1880	857,889
D . . .	80	21	1882	872,744
E . . .	80	21	1882	862,275
F . . .	90	22	1886	795,323
G . . .	90	22	1887	716,042
H . . .	90	22	1890	541,367
I . . .	90	22	1890	533,650

The total of the sixteen years, of which eleven were required for com-
pletion, is over six million tons.

W. Metcalf * gives some notes on Pittsburgh as a centre of the iron
industry.   Owing to the paucity of level ground, the manufactories are
scattered for miles along the river, and the isolation thus produced has
been a considerable drawback to the development of the town, large as

it is. Although iron ore does not exist in the neighbourhood, the unrivalled supplies of coal and coke, together with petroleum and natural gas, assure the position of Pittsburgh as a manufacturing centre. In 1859-60 the first successful blast-furnace was built, and now the city leads in the production of pig iron, as she has done in wrought iron. The steel industries, with the Edgar-Thomson steelworks, need scarcely be mentioned, and now it is proposed to bring a ship canal to this centre.

O. Williams * gives a few notes on the iron industry in the Lehigh Valley, where the first anthracite furnace was blown in during July 1840 by the Crane Company. Three years later the first Glendon furnace was at work, and in another three years the Allentown Company had a furnace. By 1855 there were about ten or a dozen furnaces in blast, owing to the great impetus given by railway communication, first opened in that year. Then, in 1860, the Bethlehem Company laid down the first rolling-mill, which has developed into their magnificent plant of to-day.

O. W. Potter † gives a summary of the early history of iron-making in Chicago. In 1857-58 a mill was built for re-rolling old iron rails, and workmen brought over from Wyandotte. The population of the town was then 85,000, and there was no railway communication with the works, so that all material was carried by water. The mill was in a wooden building 300 by 175 feet, and consisted of 17-inch ordinary two-high roughing and finishing trains. Steam was furnished by boilers heated from the reheating furnaces. The output was then a little less than forty-five tons daily. In 1863 a puddling department was added, followed by another mill in the next year to double the capacity of the works. In 1869 two blast-furnaces were added, and next year two five-ton Bessemer converters were to be built, but then the great fire occurred. Bessemer steel was first made two years later, in 1872. In 1880 the South Chicago Works were built with four blast-furnaces 75 by 20 feet, three ten-ton converters and three-high mills. The author also traces the various changes in the proprietorship, and gives some details as to capital at the various stages.

American Blast-Furnace Practice.—F. B. Richards ‡ states that the prejudice against the fine ores from the Mesabi district is diminishing, and it is now chiefly a question of cost. No furnaces have been

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* *Iron Age*, vol. lvii. pp. 31-32.
† *Ibid.*, pp. 30-31.
‡ *Iron Trade Review*, vol. xix. No. 1, p. 17.

built especially to treat these ores, but several have been slightly modi-
fied. In most cases the tendency has been to increase the size of the
hearth, and to lower the bosh so as to bring the point of scaffolding
within or close to the melting zone. Explosion doors on the down-
comers, and on the top of the furnace above the charging-line, have been
built. There has also been a tendency to provide a larger downcomer
area. In one case several downcomers connected to a common bustle
pipe are being put in. The object is to reduce the velocity of the gas, so
as to allow it to deposit dust in spite of the more rapid driving that now
obtains. A satisfactory way of using the dust has not as yet been
devised. Where the dust does not cause trouble it is due to compara-
tively slow driving. One company is at present working on a scheme
of sintering together the dust and soft coal, laid on alternate layers in
heaps 30 by 15 feet and 10 feet high.

G. R. Johnson * describes the blast-furnace at Embreville, Tennessee,
and the ores and product. The furnace is 80 feet high with 19 feet
boshes. It first ran about a year, making 100 tons daily of fair iron,
but now it makes 80 to 90 tons, principally of high grades. More could
be made by rapid driving, but as the ores are soft brown iron ores, the
product is inferior. At the present time the average phosphorus content
of the pig iron is 0·12 per cent., and is sometimes as low as 0·08;
manganese averages 0·4 to 0·5, and silicon is readily controlled. The
tensile strength is very high, being 24,000 lbs., and the transverse
strength 2200 lbs. The iron is red-short, but on account of its strength
and purity, and of its scrap-carrying qualities, it is advantageous in
mixtures. Lead occurs both in the ore and in the limestone, and though
it is not in sufficient quantities to run out with the iron, yet it occasions
trouble by causing the iron to part with its graphite. The iron has
therefore a close-grained appearance. The ore and limestone are worked
in the vicinity. The ore is washed in log-washers, and contains a high
proportion of smalls.

The A furnace at the Maryland Steel Company during the month of
January produced 8675 tons of pig iron, a daily average of 279¾ tons.
The best day's work was 321 tons, and the best week's 2019 tons. The
fuel consumption was 2038 lbs. per 2240 lbs. of pig iron. The ore
used was foreign, one-third Mokta, one-third Tafna, and one-sixth each
Porman and Seriphos, the mixture giving 55 per cent. of iron.*

* *Transactions of the American Institute of Mining Engineers*, Pittsburgh Meeting,
1896. Advance proof.

† *Iron Age*, vol. lvii. p. 357.

It is stated * that work is rapidly progressing on the four blast-furnaces building at the Duquesne works of the Carnegie Steel Company near Pittsburgh. These are to have 20-foot boshes and to be 100 feet in height. The ore is to be stored in bins arranged to minimise handling. Gas is to be taken off by six openings connected by a circular pipe to the downcomer, and an exceptionally large dust-catcher is to be provided. A double bell is to be used, each being worked independently, and one bell being over the other to act as a gas-trap and to prevent entrance of air. The capacity of each furnace is rated at 450 to 500 tons daily.

The concentration of Bessemer pig iron production in the central west of the United States has given a great impetus to the ironworks of the Mahoning Valley. Within a distance of thirty-seven miles there are twelve blast-furnaces, twelve steel plants, and one rolling-mill. The daily out-turn of the furnaces is estimated at 2500 tons, of the mills 2000 tons, and of the steel plant, which was started last year, 800 to 1000 tons. During the last year, most of the furnaces have been improved in some way by relining, adding stoves, or otherwise. Some illustrations of several of the plants are given.†

J. Birkinbine ‡ in a monograph covering 128 pages and published in the annual report for 1894 of the Bureau of Industrial Statistics in Pennsylvania, deals with the manufacture of pig iron in that State. The following comparative statements of cost, in dollars, of manufacture are given for (I.) a Southern furnace, (II.) a Western Pennsylvania furnace, (III.) an Eastern Pennsylvania furnace, and (IV.) a Western Pennsylvania furnace producing Bessemer pig iron.

	I.	II.	III.	IV.
Fuel	2·75	1·65	3·40	6·25
Ore	2·66	4·25	4·80	1·70
Limestone	0·13	0·38	0·30	0·50
Raw materials . .	5·54	6·28	8·50	8·45
Labour at furnace . . .	0·81	0·85	0·80	0·85
Supplies	0·37	0·36	0·30	0·40
Totals . .	6·72	7·49	9·60	9·70

These figures are not wholly comparative, as royalties, renewals, interest, and other factors are omitted.

* *Iron Age*, vol. lvi. p. 1105.
† *Iron Trade Review*, vol. xxix. No. 1, pp. 9–13.
‡ *Annual Report of the Bureau of Industrial Statistics, Pennsylvania, for* 1894.

J. C. Foster * gives some particulars of the iron ores in the Sheffield district in North Alabama and Tennessee, and their adaptability to the production of steel.   The following analyses are given :—

| | Ores. | | Limestone. | Coke. | Iron, 2 F. |
	Franklin County.	Wayne County.			
Iron	50·00	49·00	0·30	1·00	93·50
Phosphorus	0·65	0·80	...	0·014	1·10
Manganese	0·20	0·20	...	...	0·20
Sulphur	0·05	0·05	...	0·63	0·035
Silica	7·10	11·00	0·60	10·00	...
Alumina	6·00	3·00	1·00	4·10	...
Lime and magnesia . .	...	...	55·20	1·50	...
Silicon	...	...	...	...	1·85
Carbonic anhydride . .	...	..	42·70	...	...
Fixed carbon . . .	...	...	...	81·40	3·00

The History of Iron.—Further chapters† of the abridged translations of L. Beck's "History of Iron" have appeared.   In these iron-founding during the sixteenth century is first dealt with.   When the application of water-power made the production of pig iron possible, the first products of the founder's art were anvil blocks, stamp irons, and cannon balls. With further progress it was seen how to make grey iron, and better and smaller castings could be made.   Cast iron guns were made, and iron stove-plates became a favoured product of the founder.   The manufacture of these is described at some length from the historical aspect, and a list of the artillery pieces possessed by the town of Strassburg in 1590 shows guns ranging from 10,000 lbs. downwards.   Some illustrations are also given of highly decorated breastplates and helmets.   The marks of famous makers of armour, both offensive and defensive, are given.   Towards the end of this century, the development of firearms began to encroach upon the activity of the sword and dagger smiths, and many trade disputes occurred between them and the manufacturers of cutlery.

A number of illustrations of iron articles found in ancient Egypt have been published.‡ They include axes, hoes, chisels, saws, hammers, and various weapons.   In the neighbourhood of Waddy Mokatteb, the

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* *Iron Age*, vol. lvii. pp. 242–243.

† *Ibid.*, vol. lvi. pp. 786, 936 ; see *Journal of the Iron and Steel Institute*, 1895, No. II., p. 473.

‡ *Industries and Iron*, vol. xix. pp. 477–478.

Written valley, enormous quantities of partially buried slag have been found, and the whole district shows traces of iron furnaces and mines. The slags are said to contain 30 to 50 per cent. of iron.

Among recent archæological publications are notes on the ironworks of Huntington Shaw, blacksmith, by R. G. Rice,[*] and notes on three early iron age brooches from the Island of Gotland, Sweden, by J. Curle.[†]

II.—CHEMICAL COMPOSITION OF PIG IRON.

Value of Materials in Iron Manufacture.—W. B. Phillips [‡] comments upon the importance attached to analyses of raw materials at the present time, as compared with their neglect thirty years ago, and then discusses the value of the ore, coke, and flux as affected by their composition. From the figures deduced, the author calculates the cost of manufacturing pig iron, giving examples of his methods. It is suggested that all materials should be bought on the unit basis, limestone and dolomite on the unit of silica, and coke on that of ash.

Austrian Pig Iron.—C. von John and C. F. Eichleiter [§] give the following results of an analysis of pig iron supplied by the Union Ironworks :—

Silica.	Sulphur.	Phosphorus.	Manganese.	Nickel.
0·50	0·084	0·21	trace	trace

Japanese Pig Iron.—A sample of Japanese pig iron has been shown in Middlesbrough.[||] It was made at the only furnaces that exist in Japan, from native ore, smelted with native coke. The iron is of good No. 3 quality, and was sold in London at 38s. per ton ; but it was brought over under exceptional circumstances, and could not profitably have been sold at that figure if the regular freight, which is about £1 per ton, had been paid. It was carried partly as ballast in a tea ship, and samples of it were left at each port of call, so that the freight paid was very small. On analysis, the pig iron was found to contain :—

* *Journal of the Royal Archæological Institute,* vol. liv.
† *Proceedings of the Society of Antiquaries of Scotland,* 1895, May 13.
‡ *Proceedings of the Alabama Industrial and Scientific Society,* vol. v. pp. 36–43.
§ *Jahrbuch der k.k. geologischen Reichsanstalt,* vol. xlv. p. 21.
|| *The Engineer,* vol. lxxxi. p. 125.

Silicon, 3·26 per cent., as against 2·8 per cent. in a representative Cleveland pig; sulphur, 0·38 per cent., against 0·04; phosphorus, 0·81, against 1·46; and manganese, 1·44, against 0·52. It is stated that in Japan it is never used alone for foundry purposes, but is mixed with Cleveland iron.

Analysis of an Old Mine Rail.—A search made in the Cape Breton district for deposits of coking coal low in sulphur led to an inspection of an old mine which had been abandoned for twenty years. Fletcher, the Government geologist, noticed in this some short lengths of old rails, which attracted his attention. O. Herting * reports that a sample piece from one of these was sent him for analysis. It was of grey-brown colour, and had the specific gravity of 2·053. It could be cut with the knife, and was readily powdered in a mortar. This powder was completely magnetic, and analysis showed it to have the following composition :—

	Per Cent.
Silicon	14·20
Carbon (graphitic)	24·20
Phosphoric anhydride	13·37
Manganese oxide	2·50
Ferrous sulphide	1·37
Ferrous sulphate	2·38
Magnetic oxide (Fe_3O_4)	39·34
Total	97·36

Combined carbon was entirely absent, as also were arsenic and copper, but traces of ammonia, lime, magnesia, and alumina were detected.

Segregation and Means to Lessen its Effects.—T. D. West † again recurs to the effect of segregation on castings, and discusses some method to lessen its effects. The term is often used to excuse faults in the material or in the labour; but segregation has of itself much to answer for. Some examples of the concentration of metalloids in different parts of the crucible of the blast-furnace are given by quoting analyses of pigs from different parts of the casting-bed, especially when the furnace has been working irregularly. These relate mainly to sulphur and silicon, but phosphorus and carbon are also discussed. It is suggested that the pig iron manufacturers should in the first place care-

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* *Chemiker Zeitung*, vol. xx. p. 54.

† Paper read before the Western Foundrymen's Association through the *Iron Age*, vol. lvi. pp. 1210-1211.

fully mix the pigs when loading them. In the foundry the author is accustomed, when using two or more grades of pig iron, to bring each grade to the cupola stage on separate buggies, and then to mix them pig by pig in one-ton lots. The uniformity in mixing is held to be more important than any probability of danger from segregation, properly so called.

III.—*BLAST-FURNACE SLAG.*

Slag Bricks.—J. Bareš * observes that slag from chamoisite makes excellent bricks. The granulated slag sand is mixed with milk of lime of 8°-10° (Balling) strength, and at once moulded. Styrian siderite slag sand, on the other hand, is mixed with milk of lime of 18° strength, and then allowed to stand for twenty-four hours before moulding. The " white " bricks should be allowed to stand eight days before being subjected to transport, but " black " slag bricks must be stored for three months first. The lime from black bituminous limestone gives the best results. The slag must be rapidly and completely cooled on granulation, and the milk of lime that is used as a binding material for the slag sand must contain no anhydrous lime.

Slag Cement in Germany.—F. H. Mason,† United States Consul at Frankfort, Germany, has reported upon the slag cement industry of Germany. About 1863 the proprietors of the Georg Marie blast-furnace in Westphalia produced a slag cement, and described the process. The possibilities of thus disposing of the hitherto worthless slag were thus seen, and various methods were patented for granulating and preparing the slag, among them that of Ludwig Roth of Wetzlar. It was soon found, however, that the chief difficulty lay in the composition of the slag itself. The essential cement-making element in the basic slag is silica, and the questions to be determined were whether this acid was in sufficient proportion, whether it was in condition to readily unite with the lime, and whether there was a due proportion of magnesia and no excess of sulphide of calcium or sulphuric impurities. Repeated failures brought the whole process into disrepute, and to-day only two firms in Germany manufacture slag cement. These firms maintain fully equipped

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* *Časopis pro průmysl chemický*, vol. v. p. 345 ; *Chemiker Zeitung*, Repertorium, 1896, p. 18.

† *Iron Age*, vol. lvii. p. 912.

testing establishments, and the product is approved of and used by the engineers of Frankfort, Cologne, and other German cities. Slag cement is generally used in the proportion of one part of cement to three or four parts of sand, and requires about twenty-four hours to set. This slag cement is successfully employed in building foundations and in hydraulic construction, but it is not adapted for boiler setting, nor for use in the open air as mortar for brickwork. It is also extensively used in the manufacture of paving tiles, being for this purpose mixed with fine gravel and quartz sand, and submitted to a pressure of 500 tons in a hydraulic press. Slag from grey foundry pig, smelted under high pressure, and as free as possible from sulphur, is generally selected. A slag giving good results contains: Lime, 51·62 per cent.; silica, 35·12 per cent.; alumina, 8·53 per cent.; magnesia, 1·58 per cent.; ferric oxide, 0·87 per cent.; manganese oxide, 0·37 per cent.; sulphur, 0·88 per cent. P. Lieber, the Consul at Dusseldorf, states that there are five concerns making this cement.

A. D. Elbers * deals with questions relating to the composition of hydraulic cements, and discusses the use of blast-furnace slag in their manufacture.

Peculiar Product from a Charcoal Blast-Furnace. — J. T. Donald † describes a peculiar material thrown out on two occasions from the slag notch of the charcoal blast-furnace at Radnor Forges, Quebec. The charcoal used is made from bass wood and elm. In the furnace four 3½-inch tuyeres are used, giving 2638 to 2827 cubic feet of blast at 5¾ lbs. pressure and 900° F. The cubic contents from the stock-line is 1264 cubic feet. The material in question showed a framework of fibrous mass not unlike hard-fibred asbestos, and formed 41·16 per cent. of the charcoal. On examination it did not seem that this was part of the original vegetable growth. Analysis of the ordinary slag and of the fibrous material showed—

	Al_2O_3.	FeO.	MnO.	CaO.	MgO.	SO_3.	SiO_2.	Alkalies, Phosphorus, &c.
Slag .	13·52	1·44	3·48	22·89	0·74	1·52	54·00	2·41
Fibres	18·15	0·51	trace	35·44	1·47	trace	42·18	2·25

It is assumed that this material really consists of slag absorbed by the charcoal, but no explanation can be given.

* *Engineering and Mining Journal*, vol. lxii. pp. 373–374.
† *Ibid.*, p. 281.

IV.—FOUNDRY PRACTICE.

American Foundry Practice.—C. A. Hague * describes a large foundry built in a town. The ground available was L-shaped, with legs 100 feet and 250 feet long, and both about 60 feet deep. The short leg was used for a three-storey building, with a machine shop and a storage shop on the two upper storeys. The basement underlies the whole area, and also the street pavement on two sides to a depth of 16 feet. This floor is laid with concrete, and is used for storing materials. The main or ground floor is four feet above street level, and is supported on columns, girders, and floor beams. The floor is of 2-inch planks, covered with brick, and though it was feared that vibration from the machinery might affect the castings, no detrimental action occurred. The longer leg of the building is single storey, with a truss roof, and forms the moulding floor. The cupolas, two in number, are contained in a fire-proof building placed in the angle of the L. The molten metal is distributed by two 1500 lb. tipping ladles. A full description is also given of the shaft and belt system for transmission of power to the blowers and the tumbling, grinding, and other machinery.

Some particulars have appeared † of a foundry at Newport News, Virginia. The main building is 200 by 85 feet, and is controlled by a 25-ton and a 10-ton travelling crane. There are three cupolas, one 48 inch, one 35 inch, and the third a small one.

J. A. Brady ‡ offers some remarks on the jobbing foundry which is often started by manufacturers to make special castings for themselves, and then extended to do odd work at low prices in order to cover the cost. The poor quality of the work is especially commented upon.

J. Goye § comments upon several causes of waste in the foundry. Amongst others, mention is made of steam leakage, lack of proper weighing appliances, and consequent guess-work in the selection and use of materials. Disorder, bad arrangement, and faulty appliances are fertile sources of waste.

A Curious Foundry Accident.—During the manufacture of a large kettle used for melting lead, a curious accident recently occurred. The

* *American Machinist*, through the *Iron Trade Review*, vol. xxix. No. 1, pp. 14–16.

† *Iron Trade Review*, vol. xxix. No. 7, p. 13.

‡ Paper read before the Western Foundrymen's Association, through the *Iron Age*, vol. lvi. pp. 837–838.

§ *Iron Trade Review*, vol. xxix. No. 1, pp. 29–31.

kettle was 11 feet 5 inches in diameter, 2½ feet deep in the centre, and 3 inches deep at the sides. Whilst the core was being put into place it was found necessary to raise it, and when it had been lifted some eight inches the chain broke. Although the core weighed some 14,000 lbs., the air broke its fall so successfully that it was uninjured.[*]

Cupola with Central Tuyere.—Illustrations [†] have been published of the Crandall cupola with the Johnson central tuyere. The central tuyere terminates about one inch above outside tuyeres, and over it a short length of tube is placed, and then a cap, this tube and cap being spaced apart from each other, and from the tuyere by pins so as to leave two annular openings. The tuyere is fixed, and the drop-down door closes over it. In some instances the ordinary tuyeres are dispensed with altogether.

Ingot Mould for Irregular Sections.—A metal ingot mould for casting irregular sections devised by A. Reese has recently been illustrated.[‡] When the metal is poured into a mould made in halves, the interior surface expands, and so the parts tend to separate at the top and bottom if the division is vertical, and this tends to break the bolts which holds the parts together. To avoid this, eye-bolts are used, and a rod bearing on one half of the mould is passed through the eyes, whilst the other ends of the bolts bear nuts which are tightened up against the lugs on the second half of the mould. These rods bend when expansion takes place, and the return is prevented by wedges which drop down between lugs placed on the two halves of the mould.

Cylindrical Casting Ladles.—Illustrations have been published [§] of a ladle designed by W. Hainsworth for casting iron and steel. It consists of a steel cylinder with removable ends. Each end is provided with trunnions, one of which is hollow and lined like the cylinder with refractory material. The trunnions are placed eccentrically near the circumference, so that the lining in the hollow one and in the cylinder coincide with one line. With this arrangement, when the cylinder is in the top position it can be entirely emptied. A manhole is placed somewhat to the side of the top of the cylinder, so that the molten metal never comes into contact with the cover. A funnel replaces the cover when the ladle

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[*] *Iron Trade Review*, vol. xxix. No. 4, p. 8.
[†] *Iron Age*, vol. lvii. p. 588.
[‡] *Ibid.*, vol. lvi. p. 995; *Iron Trade Review*, vol. xxviii. No. 46, p. 12.
[§] *Iron Age*, vol. lvi. pp. 1315-1317.

is being filled. The cylinder is revolved to empty it by stationary or movable winding-gear. This ladle is used for conveying molten iron to the converter, for casting iron or steel, and for other purposes. Its great advantage is that its pouring orifice, which really is one of the trunnions, always remains at the same height whilst the ladle is being tilted. A pouring trough is sometimes attached to the carriage.

Hydraulic Machinery in Foundry Practice.—F. Wüst * observes that the use of mechanical power in foundry practice only began to find general application in the seventies. There is a wide field for the use of machinery in this direction, and the author points to some of the uses to which such power may be put. Hydraulic power is especially valuable for this purpose. It is better, he thinks, than the use of electricity, for reasons which the author deals with, and he describes, with the aid of numerous illustrations, some of the hydraulic machinery employed in such work.

Iron Castings.—F. Bleichsteiner † observes that the different varieties of iron castings may be divided into two main groups—(1) those of pig iron, and (2) those of ingot iron or steel. With regard to the former, they may be further subdivided into "grey" castings, "chilled" castings, and "tempered" castings. To produce grey castings only grey pig iron can be employed, which, in consequence of its chemical composition, has the property of completely filling the moulds and not cracking on cooling. These castings are made either direct from the blast-furnace or after first remelting the pig iron. As a rule, pig iron that has to be remelted in this way must be deep grey. It is not always possible to start a blast-furnace, and to produce with advantage a pig iron suitable for direct castings, although by suitable mixture of the ores smelted an otherwise satisfactory pig iron may be obtained. A peculiar property of some kinds of castings consists in their capability of withstanding very considerable changes of temperature by rapid cooling without cracking. The Werfner ingot mould metal is particularly famed for this, but it is only occasionally possible to produce by remelting a pig iron of similar quality, although the chemical composition of the metal is known. It contains 3·279 per cent. of carbon, 1·593 of silicon, 1·183 of manganese, and 0·062 of phosphorus. The phosphorus contents of pig iron greatly increases its fluidity. If at the

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* *Stahl und Eisen*, vol. xv. pp. 994–1002, with seventeen illustrations.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. pp. 515–519.

same time the percentages of silicon and of graphitic carbon are very small, and no manganese is present, direct castings of good marketable quality can be made even when not inconsiderable quantities of sulphur or copper are present in the pig iron. A cupola casting plant should make at least 25,000 tons of castings yearly. Its working should be so regulated that for every 100 lbs. of castings from 5 to 8 lbs. of coke should not be exceeded, and the loss of metal not more than 3 or 4 with an out-turn of 1000 tons per run. Hot-blast and strong blowing appliances should be employed.

With regard to chilled castings, the composition of the pig iron best suited for their manufacture is: Sulphur, not more than 0·8 to 1·2 per cent. ; manganese, not more .than 1·8 per cent. ; carbon, at least 3·8, and phosphorus, at most 0·14. With less than 0·6 per cent. of silicon the metal is useless for casting purposes. Still, notwithstanding this knowledge, and notwithstanding the use of the best possible cooling arrangements, success is not always attained as soon as it becomes a question of dealing with large castings. Sometimes the fault consists in surface cracks, sometimes in unequal degrees of hardness, and often too brittle a metal is the cause. The author thinks that chilled rolls may best be made by the aid of reverberatory furnaces, as then the percentages of silicon in the pig iron must be small when that of the combined carbon is high.

With regard to tempered or malleable castings, the author observes that these castings really replaced cheaply a large number of small wrought pieces, which, according to the circumstances of the case, would have been of weld iron, ingot iron, or steel. Very grey pig iron, as low as possible in manganese, and with but little silicon, is best for these castings. It requires, however, to be mixed in accordance with the thickness of the casting. The casting itself must be perfectly compact and of very fine grain. The best results are obtained with the addition of aluminium.

Castings of ingot iron and steel are next considered, and the author observes that, after all, very little is known as to the real cause of many of the mechanical properties observed in connection with the treatment of steel. Steel castings solidify rapidly, and it is consequently not possible to readily produce faultless castings of steel of less than 10 millimetres in thickness. Steel or ingot iron castings, the author adds, do not crack so readily in the cold as rolled or hammered ingot steel, and he points to the progress which has been made of late in the uses of such castings.

A description has been published,* from the pen of a foreman moulder, of Scotch foundry practice, with special reference to the casting of pump pipes.

Further instalments have appeared of an exhaustive series of articles on modern foundry practice, published in *Engineering*.†

Pattern-Making.—J. L. Gobeille ‡ notes the fact that there has been but little published concerning improved methods of making patterns for castings. He describes and illustrates a pattern which weighed under 46 lbs. made for a 36-inch railway wheel. This pattern is one of thirty-six made for a railway company. The faces were turned of cherry-wood and the hub built of pine. The ribs and wearing faces were made of hard aluminium alloys containing 99 to 95 per cent. of aluminium.

The Preparation of Moulding Sand.—A. E. Outerbridge § discusses moulding sand and its preparation for the foundry. The essential qualities are toughness and porosity, and these are antagonistic, as the clay which gives adhesiveness tends to fill up the pores. It is seldom that the proper proportions of the sand and clay are uniformly distributed in a bed of the material. Some parts are "too fat" from excess of clay, and the rest too lean or sharp, so that the sand must be riddled, trodden, or reworked, and moulders often consider the carrying out of these opera-tions as a trade secret. But little has been published on this subject, and the expert trusts solely to the feel of the damp sand as he squeezes it up into a ball in his hand in order to determine the quality. The microscope and a small washing-pan, similar to that used by gold-diggers, are, however, valuable aids in determining the composition. Good moulding sand contains 5 to 10 per cent. of clay, which forms the binder, and this can readily be washed out and the remaining sand weighed. The washing may also be used to determine the various proportions of fine and coarse sand. Iron and magnesia are also present, but are unimportant.

Various mixtures of sand with flour, coal-dust, and other materials are used, according to the nature of the moulds and work, and the individuality

* *Engineer*, vol. lxxxi. p. 79, with eight illustrations.

† Vol. lx. p. 789; vol. lxi. pp. 106, 239, 494, 701.

‡ *Iron Trade Review*, vol. xxix. No. 1, p. 23.

§ Paper read before the Western Foundrymen's Association, through the *Iron Age*, vol. lvii. pp. 415–417, with illustrations.

of the moulder, and there is considerable difficulty in properly mixing these substances so as to obtain uniformity by hand labour.   Much better results are obtained by centrifugal machinery. One machine is described by the author in which the mixture is fed from a hopper on to a horizontal revolving plate provided with a number of circular rows of vertical prongs. This plate revolves inside a casing, thoroughly mixes the sand, and throws it out centrifugally well broken up.

Moulding Machines.—In the moulding machine designed by A. B. Kilpatrick * the table is composed of a number of parallel strips separately adjustable by cams, so that any number can be raised to make a desired pattern.

Venting Moulds.—D. Brown † describes the operation of venting moulds for castings. The proper arrangement of vents is of vital importance, especially in green sand moulds, in order to allow the escape of gases. With dry sand or loam it is not of such great importance. Wires from $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter and 1 to 4 feet in length are used over the tops, and also at the sides to make passages connected to a common channel, which is filled with straw rope, and ashes. In heavy castings the sand is moulded on the top of a layer of ashes which is connected to the surface by several tubes rammed up in the sand round the pattern. When the pattern is withdrawn the vent wire is freely used.

The Working Time of Moulders.—At a recent meeting of the Western Foundrymen's Association the following questions were discussed : ‡—(1.) Does the employer derive any benefit from compelling moulders to remain in the foundry until quitting time if their moulds have been poured off before ?   If so, what benefit ?   (2.) Are there characteristic conditions in foundries which necessitate different practice and management from those followed in other industrial pursuits ? (3.) Is the moulder in a fit condition to do further work after he has poured off his day's moulding ?

Naturally very diverse opinions were expressed in the course of this discussion, and it seems that in the United States the practice is very variable. In many cases the men go after they have poured their moulds,

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* *The Age of Steel*, vol. lxxix. No. 10, p. 7.

† Paper read before the Liverpool University College Engineering Society, November 26, 1893.

‡ *Iron Age*, vol. lvii. pp. 244-247.

but strong opinions were in some quarters expressed against this, as any men who were on larger jobs had to remain, and, apart from their jealousy, discipline is generally impaired. Sometimes, however, it seems to work well. Some works, again, employ special men to do the casting, but several speakers thought that the men who made the mould were best able to pour it. So much depends upon the size of the works and the class of castings made, that it is difficult to draw any general conclusions. It would seem, however, that the better subdivision of labour was very necessary, but some speakers appeared to think that works could not be carried on except each man did practically everything, from mixing and damping his own sand to stripping the castings.

At a subsequent meeting* of the same Society, there was a lengthy discussion on the apprenticeship system in the United States.

Cleaning Castings.—F. C. Brooksbank † discusses the theory of the sand-blast, and describes its numerous applications. When first invented, a steam jet was used to induce a current of air carrying the sand, but for use with ironwork the subsequent liability to rusting was objectionable. Compressed air to replace the steam in this apparatus is expensive, but now the sand is charged direct into the compressed air current, which is not required to draw in a further air supply, and great efficiency is thereby attained. Various kinds of sand are generally used, but powdered glass, emery, chilled iron, sand, and steel shot are also employed. A machine using 60 cubic feet of air per minute requires three indicated horse-power to run the compressor, supplying air at 10 lbs. pressure per square inch. This amount will remove the scale from one square foot of steel plate per minute. The author gives a long and most varied list of interesting applications of the process outside the iron and steel trades. One of the most recent applications is to combine the sand-blast with a tumbling barrel run very slowly, at two or three revolutions per minute, so as to safely clean fragile castings. Cleaning ironwork previous to painting is referred to, and it is also advocated that plates should be cleaned before riveting, so as to produce closer joints and to reduce the caulking necessary. The pernicious effects of pickling are then dealt with, and it is shown that the sand-blast may replace this process. For removing cores and generally for cleaning castings the sand-blast is most efficacious, and is far more speedy and thorough than

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* *Iron Age*, vol. lvii. pp. 749–752.

† Paper read before the Western Foundrymen's Association, March 4, 1896, through the *Iron Age*, vol. lvii. pp. 640–642.

hand-labour.   Even intricate cores are readily removed, and when a large number of nails are used in the cores, the blast eats away the sand, and lets the nails fall perfectly clean and in condition for re-use.

J. F. Clement * mentions two forms of percussive tools which can be used in place of hand-labour for cleaning castings from sand and chipping off fins.   In one form there is a transverse valve in the cylinder cover, and in the other the piston acts as its own valve.   The piston in each case is loose, and strikes rapidly on the head of the tool.   The appliance is held in the hand, and used for the purposes mentioned above, and also for caulking and other work in which a hammer and chisel is employed. Compressed air at 60 to 80 lbs. pressure is used to drive these tools. Several instances are given to show the labour and time saved; as compared with hand-work this is as 1 to 10 or 12.   In the discussion the sand-blast was also mentioned.

R. Moldenke † advocates the use of hydrofluoric acid in place of sulphuric acid for cleaning castings.   This acid attacks the silica instead of the iron.   For work left in pickle overnight 1 part of acid in 50 of water by volume is recommended, for day work 1 in 40, and for quick work 1 in 30.   The acid used is of 48 per cent. strength, shipped in lead carboys, or its weaker equivalent transported in wooden barrels.   Care has to be taken in using this acid, as burns from it are exceedingly painful.   The sand which drops to the bottom of the bath should be removed to prevent its solution weakening the bath.   To produce bright castings they are thrown into milk of lime after pickling and then washed with hot water.

The Manufacture of Chilled Wheels.—The manufacture of chilled wheels in the United States is described in an editorial article in *Stahl und Eisen.*‡   For this purpose charcoal pig iron is either used alone or in admixture with coke pig iron and iron and steel scrap. According to Freson, the percentage of manganese in the best carriage wheels must not exceed 0·50 per cent.   Those that have lasted well in practice rarely, however, contain more than 0·44 per cent., and in one instance only 0·13 per cent. was present.   The percentage of silicon varies from 0·5 to 0·7, and of phosphorus about 0·3 to 0·4.   According to Lagerwall, the Chicago, Milwaukee, and St. Paul Railway employ in

* Paper read before the Western Foundrymen's Association, through the *Iron Age*, vol. lvi. pp. 1209–1210.

† *The Age of Steel,* vol. lxxix. No. 13, pp. 12–13.

  Vol. xv. pp. 1050–1059, sixteen illustrations.

the manufacture of these wheels to every 400 lbs. of Salisbury pig iron
No. 3, 1600 lbs. of old chilled wheel scrap.

The pig iron used contains—

Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Sulphur.
3·70	0·90	1·73	0·24	0·08

The chilled wheels have the composition :—

	Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Sulphur.
Hard surface	0·16	3·75	0·54	0·33	0·10
Unhardened interior	2·55	1·40	0·60	0·37	0·35

Extreme care has to be devoted to the cooling down of the cast wheels
to allow of the equalisation of all strains due to the casting. This is
best done by removing several of the wheels as soon after the casting as
possible to walled pits, and allowing them to cool down there during
several days. The requirements for a perfect wheel are that (1) the
running surface shall be perfectly cylindrical ; (2) that it shall be per-
fectly smooth ; (3) the chill shall not be less than 10 millimetres nor
more than 20 in depth ; and (4) between the chill and unchilled metal
there shall be no abrupt line of demarcation, but both kinds of iron
must pass gradually the one into the other. The author deals with the
various causes which may lead to faulty wheels, and then passes to the
method of manufacture itself. This is dealt with in much detail.

PRODUCTION OF MALLEABLE IRON.

Catalan Forges in America.—The Helton forge built in 1859, a Catalan forge of very primitive type, is still worked by W. J. Pasley in the extreme north-west of Carolina. Its annual capacity is 75 tons, but it seldom produces more than 50 tons. Local magnetic iron ore is used, and the hammered bar iron finds a ready sale in the neighbourhood. A few years ago this industry was of some importance in the Southern United States, but now the Helton forge is the only one left. In the Lake Champlain district of New York there are seven of these forges, and in Tennessee one, but they are all of modern type. None of them, however, have made any iron during the last two years, though one may start again in New York this year.[*]

Puddling.—E. Laduron [†] describes the method of direct puddling adopted at the Bonehill Works.

A short description has appeared [‡] of the Union Steel Company at Alexandria, Indiana. The fuel used is gas, and is drawn from five adjacent wells. Puddled iron is made in conjunction with the steel, which is produced in two 5-ton converters. A brief account is given of the blooming mill, muck bar mill, sheet and merchant bar mills, foundry and machine shops.

In a paper read before the West of Scotland Iron and Steel Institute, J. Kerr [§] explains the preparation of the furnace and the puddling of a heat of iron. To begin with, the furnace bottom is first prepared by oxidising light iron, the oxide acting as a protection to the bottom plates. Fettling is then placed round the sides, and the whole forms a hollow cavity not unlike a basin. From 56 to 84 lbs. of hammer slag or roll scale is then thrown in, and the pig iron is thrown round the bottom. The average analysis of a heat of pig iron may be taken as—

[*] *The Bulletin of the American Iron and Steel Association,* vol. xxx. p. 76.

[†] *Revue Universelle des Mines,* vol. xxxiii. pp. 22–41, with two plates.

[‡] *Iron Age,* vol. lvi. pp. 1269–1270.

[§] *Colliery Guardian,* vol. lxxi. p. 750.

Carbon, combined and free	. 3·98
Silicon	. 2·13
Phosphorus	. 1·40
Sulphur	. 0·08
Iron (by difference)	. 92·41
	100·00

The pig iron is of course in half pigs, and it is at the melting stage that the puddler, by paying attention, can save himself a great deal of extra work and much loss to the manufacturer. If he is not careful to see that his iron is melted uniformly, but allows some of it to be exposed unduly to the fire, it drops at once on to the bottom and melts the oxide off the plates. Supposing the heat is now uniformly melted, the hammer or roll scale floats on the top and prevents it from being burned. The puddler is understood to have been working the iron from the time the pigs first commenced to melt, and he gradually increases the agitation as the iron becomes liquid. It is now at a sufficiently high temperature, but he still continues the agitation, and when he thinks the iron is sufficiently heated he puts on a small fire with the object of damping the furnace, and puts down the damper, thus lowering the temperature. Still he agitates till the metal becomes pasty with the lowering of the temperature, and when sufficiently thick the damper is raised and the temperature again increased. At this stage the iron mixes with the cinder, and is now on the boil, and appears for the first time in a semi-malleable form and in granular parts. It is boiling rapidly, and some impurities in the form of cinder flow over the fore-plate of the furnace owing to the increased bulk. It is now that the puddler requires to keep up the agitation to prevent it from sticking to the bottom or sides of the furnace. As it increases in temperature the cinder becomes thinner, the iron ceases to boil, and settles down or drops, and is then in a soft, spongy mass, and requires to be well and uniformly turned over and exposed to keep it at a regular heat all through. It is in this state that loss by oxidation may take place through exposure to cold air rushing through the stopper hole. The puddler now balls into four or five balls of a little over 1 cwt. each, and takes them one at a time to the hammer, where any cinder now in it is hammered out and the balls are finished in square or flat slabs and sent to the forge rolls. They are then rolled into puddled bar.

In consequence of the announcement that the Bowling Iron Company have given up the manufacture of rolled iron, a description has been published * of the method of manufacture of best Yorkshire iron.

. * *Engineer*, vol. lxxxi. p. 296.

FORGE AND MILL MACHINERY.

The Equipment and Working of Rolling-Mills.—In a paper on American and English methods of manufacturing steel plates, Jeremiah Head[*] stated that in England the intermediate process of cogging was now almost universal, whereas in the United States plates were usually rolled direct from ingots. The former plan permitted the use of larger ingots, and lessened the risk of wasters, as well as reducing the number of ingot moulds in use and slightly decreasing the waste in scrap. On the other hand, it entailed two reheatings instead of one. An American melting-house, in which the ingots were poured from the top and subsequently cogged, was described. It was arranged on the ground-level, with the exception of a small pit for the reception of the casting ladle. When full, this was lifted by an electric crane and poured into a series of ingot moulds, each standing on a bogie. These were then taken to the stripping-house, where an overhead hydraulic stripper held the ingot firmly down and at the same time stripped off the mould. In a typical English melting-house the furnaces were on a charging platform, while the ingot moulds, standing in a casting pit, were filled from a travelling ladle. The moulds and ingots were lifted by steam-cranes in front of the furnaces. A comparison of the number of lifts on the English and American systems showed an advantage in favour of the latter. Ingot-soaking furnaces were heated by coal, or by producer or natural gas, except in one case in Scotland, where no external heat was applied. Vertical furnaces with the lids level with the floor were in favour both in England and America. Where direct rolling was adopted, the ingot moulds were arranged in groups of six on a base-plate, and filled from below by ducts radiating from a central runner. The upper ends of ingots so made were usually sounder than if they were cast from the top. The typical American plate-mill consisted of a single stand of three chilled rolls, driven by a single-cylinder non-reversing engine through a set of three pinions. The middle roll,

[*] *Minutes of Proceedings of the Institution of Civil Engineers,* May 5, 1896.

which was smaller in diameter than the upper two, was not driven. A copious supply of water kept the rolls constantly cool. The live roller tables in front and behind were pivoted, and were raised and lowered to admit the piece through the top or bottom openings. The English plate-mills consisted of two stands of two rolls each, worked dry and driven by a pair of reversing engines. There were fixed live roller frames on one side and a traversing one on the other. The American method of rolling an ingot tapered in two directions into a rectangular plate of equal thickness was next described. In England, the cooling and flattening of the plate was effected on an iron-plated floor, and required a considerable amount of space and manual labour. During shearing, the plate was manipulated by a gang of twelve men. A truck with universal motion had been introduced to assist in this operation, but had not been generally adopted. In America, the plates as they left the rolls moved slowly along a series of live rollers, 360 feet long, cooling on the way. At the far end, having been inspected and marked in transit, they were delivered to the shears. During the shearing operation the weight of the plate was supported by a number of inverted castors, which allowed it to be moved horizontally in any direction. The sheared plate was deposited in the railway waggons by an electric crane. The ratio of saleable plates to ingots was much higher in steel than in wrought iron manufacture, because of the smaller furnace waste and the smaller allowance necessary for shearing. A table was given comparing results where ingots were cogged and where they were rolled direct. A plate-mill, supplemented by a cogging-mill, had nearly twice the capacity of one not so assisted. The yield and output were largely influenced by the shape and size of the plates manufactured. The turning of the rolls to ensure uniformity of thickness of the plates was a somewhat delicate operation. The central portion of the roll was apt to become hotter than the ends, and the differential velocities thus caused tended to produce buckling of the plate. To compensate for this the rolls were often turned slightly hollow. A fresh difficulty arose in rolling very broad plates by the springing apart of the rolls. This could not be altogether avoided, and could only be minimised by making the rolls as stiff as possible and keeping them cool. The American standard plate-mill was not suitable for very narrow or thin plates. It was therefore sometimes supplemented by a universal mill for strips of breadths not exceeding 3 feet. The English standard plate-mill was smaller than the American, and was often supplemented by a larger mill for very broad plates, and also

by a sheet-mill. Modern English plate-shears were driven by a pair of reversing engines which were capable of cutting 2-inch plate without a flywheel, and were somewhat larger than American shears. The latter were driven by a single cylinder with a flywheel.

In a paper on "Four American Rolling-Mills," by Samuel T. Wellman,* four mills, typical examples of modern American practice, were described, in reference more particularly to the appliances which during the past ten or eleven years had been brought to a high degree of perfection to save labour and time in the passage of the material through the successive processes. In American Bessemer steel-works where rails were made, the three-high blooming-mill was almost exclusively used, having proved its superiority for producing large quantities of blooms of one size. The two-high reversing-mill was, however, preferable when many sizes of blooms and slabs had to be manufactured, as all sizes of squares and flats within the range for which the mill was adapted could be dealt with on one set of rolls. The tendency was in the direction of the manufacture at every works of all sizes and shapes, so that it seemed likely that the reversing-mill would largely take the place of the three-high blooming-mill. The use of the three-high or Fritz mill was almost universal in the United States for finishing rails and other heavy bars. At the Joliet Works of the Illinois Steel Company the rail-mill was fitted with automatic machinery, and the blooming-mill was equipped with Siemens regenerative ingot-heating furnaces and Wellman electro-hydraulic charging machines. The ingots were brought in front of the heating furnaces from the converting works on waggons, and all the operations for dealing with them at the furnaces were effected by these machines, the power for driving which was stored in a tank charged, first with air to a pressure of 100 lbs. per square inch, and then with water until the pressure reached 400 lbs. per square inch. The ingot, on leaving the furnace, was carried on a waggon driven by a wire-rope to live roller tables, along which it travelled to a three-high Fritz mill with the three rollers fixed, the ingot, measuring 16 inches by 6 inches, being rolled in thirteen passes to $7\frac{1}{2}$ inches by $5\frac{1}{4}$ inches. The bloom was carried over driven rollers to the bloom shear, where the ends of the bloom were cut off and the remainder cut in two pieces, each of which was rolled into two rails. The scrap bloom ends dropped on a conveyor in the pit under the shear, by which they were lifted and dropped into waggons. The blooms now passed from the shears, first to the roughing rolls, at which they were manipulated by automatic machinery, then to

* *Minutes of Proceedings of the Institution of Civil Engineers, May 5, 1896.*

the finishing rolls and on to the saws.   The greatest output of the mill
in twelve hours had been 679 tons of billets, and the best month's work
27,003 tons, the average output being about 500 tons per shift of
twelve hours.   The number of men employed was thirty-five per shift.
The rail-mill at the South Works of the Illinois Steel Company, South
Chicago, was equipped with a three-high blooming-mill and finishing
train, the ingots being heated in vertical gas-furnaces of the Siemens
type, arranged to use producer-gas or crude petroleum.   The ingots were
drawn in and out of the furnaces by Wellman hydraulic cranes.   The
rail trains were 27 inches diameter, and were fitted with lifting and
tilting roller-tables for carrying the bloom through the successive passes.
The capacity of the mill was very great, 1025 tons of rails having been
rolled in twelve hours and the monthly output having reached 38,093
tons.   The new rail-mill at the Edgar-Thomson Steelworks was next
described.   Its capacity had hitherto not been fully tested, but a
monthly output of 38,300 tons of rails had been reached.   The new
plate-mill of the Illinois Steel Company was the largest and most com-
plete in the United States.   The train consisted of two stands of rolls
of the Lauth three-high type, capable of dealing with ingots 24 inches
thick and weighing 7 or 8 tons.   The heating furnaces were of the
Siemens type and were charged by electro-hydraulic charging machines.
Electric cranes were used for lifting and moving the plates at the cool-
ing beds, for dealing with them at the shears, and for loading them into
the railway waggons.

The Replacement of Rolls by Presses.—J. Buch [*] describes a
process patented in Germany in which the preliminary rolling of an
ingot is replaced by treatment in a press.   As long as the preliminary
shaping of the ingot has to be effected in a train of rolls, then in the
case of shaped iron there are limits to the maximum dimensions of the
shape.   By replacing rolls by presses the difficulties of manipulation
that had to be encountered when using numerous trains of rolls are at
once eliminated, and the maximum limits above referred to capable of
being largely exceeded.   The author claims, too, not only that the new
method is cheaper than the old, both as regards plant and working costs,
but that it is more rapid, and that the metal under treatment keeping
much hotter, shapes of lesser weight can be produced than is possible
when rolls are used.   He describes the use of presses and their arrange-
ment, numerous illustrations being also given.

[*] *Stahl und Eisen*, vol. xv. pp. 1143–1149, thirteen illustrations.

An illustration has been published * of a double-power hydraulic press, which can be worked at either 100 tons or 200 tons power at will.

Three-High Rolling-Mill in Bavaria.

Three-High Rolling-Mill in Bavaria.—Detailed drawings have been published † of a three-high rolling-mill at the Maximilianhütte at Rosenberg, in Bavaria. The rolling-mill was supplied in 1892, and has worked satisfactorily for three and a half years.

Rolling-Mill Tables.—Illustrations have appeared ‡ of a feed-table for rolling-mills, designed by J. A. Potter. The ingot or bloom from the rolls is received on a number of endless chains, which are provided with rollers at the junctions of the links. These run over a plate or table, at the end of which are sprocket wheels, and the chain on its return under the plate dips into a water-tank. Owing to the rollers, the chain only travels half the distance of the work. The ends of the table farthest from the rolls are pivoted, and the opposite ends are raised or lowered simultaneously by a hydraulic ram.

In the feed-table designed by S. E. Forbes, § the live rollers are driven by worm gearing instead of by spur gearing. The worm shaft is placed in the table under the ends of the rollers, and has on it a number of worms engaging worm wheels on the ends of the rollers. This is stated to work satisfactorily, and to avoid the breakage that occurs with the teeth of toothed gearing.

Illustrations have been published ‖ of the transfer table designed by O. V. Huber for the rolling-mills of the Ohio Steel Company. The rollers on which the work is received from the rolls are overhung so that the transfer table can come in between them to pick up the material. This transfer table is mounted on a carriage which runs on a track that can be raised or lowered by hydraulic power. The work can be turned on its side as the carriage is traversed by means of arms working over a curved guide, which can be put in or out of position, and these arms turn the heads on the table which come up between the rollers to receive the rolled bar. The table is so arranged that it can receive from, and deliver to, two alternate passes alternately, and the work can also be delivered flat or on edge. Two different articles can thus be rolled alternately. The valve arrangement is automatic.

A long paper on the working of iron and steel by E. Demenge

* *Engineer*, vol. lxxxi. p. 316.
† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 1–2.
‡ *Iron Trade Review*, vol. xxix. No 7, p. 8. § *Ibid.*, p. 13.
    Iron Age, vol. lvi. pp. 833–836.

appears in the *Revue Generale des Sciences* for October 15 and 30. The article is illustrated by twelve full-page plates, chiefly representing modern forging and rolling machinery.

Iron and Steel Works at Pittsburgh.—Some notes on several of the iron and steel works in Pittsburgh have been published * in connection with the recent visit of the American Institute of Mining Engineers. Jones & Laughlin's, Limited, have now abandoned all their puddling furnaces, and work two 9-ton converters and two 20-ton open-hearth furnaces. Especial attention is paid to cold-rolled steel shafting. The rolling-mills have a capacity of 500,000 tons per annum. One of the older mills is still driven by belts from overhead shafting. A recent addition consists of continuous roll trains for bars. Of the two, one is used as a finishing mill, receiving blooms rolled to about 6 by 4 inches from a reversing-mill, and rolls them down without reheating to various sizes of flat bars. The other is an independent mill, which takes 4 by 4 inch reheated billets and rolls them down in nine continuous passes to a rod about $1\frac{1}{2}$ inch diameter, which is then passed by hand into an ordinary guide-mill, and finished in three passes to a 1-inch round or other rod. The reheating furnace is continuous, with an inclined bed, such as is described elsewhere in these abstracts.

At the Fort Pitt Foundry large castings are made, and also large rolling engines and mills. The Star Tin Plate Company is also described. It has just commenced work, and will have a capacity of 1200 boxes daily. The Shoenberger Steel Company makes open-hearth steel boiler-plate. Within a somewhat limited area it has two blast-furnaces, stockyard, two converters, two open-hearths, and various mills. A new continuous mill for flat bars has recently been constructed.

At the Homestead Steelworks there was shown a 50-ton armour plate being forged in the 10,000-ton hydraulic press. It was handled by an electric crane, and compressed 2 inches at each stroke, being moved 6 inches after each stroke. One of the electric overhead cranes in these works is controlled from a distance, instead of carrying a driver, as is usual. A special laboratory has been fitted up for micrographic investigations. It contains an electric lantern for projections on to a screen, and various photographic appliances. The Westinghouse Electric and Manufacturing Company at East Pittsburgh was also visited, and is shortly described.

No important changes have been made recently at the Edgar-Thompson Steel Works; but the rail mill has been lengthened 300 feet, making it 1200 feet long, in order to more easily handle 60-foot rails.

* *Engineering News*, New York, vol. xxxv. pp. 159–160.

PRODUCTION OF STEEL.

CONTENTS.

I.—THE CARBURISATION OF MALLEABLE IRON.

Direct Manufacture of Steel.—C. Otto * observes that the earlier efforts at direct reduction were not successful. The iron was obtained in a very spongy form and full of slag, which was difficult to treat further, and it rapidly oxidised. The Siemens rotator method gave better results, but the cost of production was excessive, and the product very variable in character; this was rarely satisfactory, and never excellent. The author next refers to Blair's method and to that of Du Puy, which gave more satisfactory results. The author has himself devised a process which he has patented. This consists of a method for the direct production of iron and steel in a reduction vessel heated from outside and not penetrated by the products of combustion, and marked by the fact that a high-pressure atmosphere is maintained both within and without the reduction vessel, the gas from which passes to the fire that heated it. He employs a horizontal retort, and shows by theoretical calculations the advantages connected with the use of the process. It is not stated, however, whether the process has hitherto been employed in practice.

* *Stahl und Eisen,* vol. xvi. pp. 148-152.

II.—*THE OPEN-HEARTH PROCESS.*

The Basic Open-Hearth Process in Illinois.—Up to the present time two 25-ton open-hearth furnaces, one calcining furnace, and six producers have been built and worked at Granite City, Illinois.* The casting pit is remote from the furnaces, and a small slag pit with a ladle on trunnions has worked well.

The two 25-ton open-hearth furnaces have so far made 511 heats, of which only two heats were a partial loss. One of the furnaces has made 201 heats, almost exclusively below 0·10 per cent. in carbon, without any repairs; both are making 13 to 14 heats of extra soft steel per week regularly. They were designed by G. L. Luetscher. The main features are: long gas ports, which are essential for a long run on basic working; accessibility of gas and air uptakes for examination and slight repairs while charging or between heats; heavy partitions between air and gas pockets, uptakes and ports, preventing the mixing of gas and air anywhere else than in the melting chamber proper, and large regenerators. The hearth is 19 feet 9 inches by 11 feet 6 inches. At present water-cooled Siemens valves are used, but they will be replaced by water-cooled and water-sealed poppet valves of new design. The gas flues are connected with the stack flue, so that by pulling out a slide the flue can be burned out every Saturday without burning through the reversing valves. The analyses given below show the quality of the product :—

	Carbon	Phos-phorus.	Sulphur.	Man-ganese.	Silicon.
Average of first 30 heats	0·10	0·008	0·033	0·35	none
Average of second 35 heats	0·15	0·013	0·035	0·37	none
Average of present product	0·09	0·060	0·060	0·36	none
Average of axle steel, 4 heats	0·42	0·008	0·036	0·42	0·015
Average of tool steel, 3 heats	0·81	0·039	0·050	0·88	0·027

The present product is used for tin plates.

For ordinary steel the 52,000-pound charge consists of about—

25 per cent. Southern basic pig iron from Tenn. C. I. & R. R. Company, containing about 0·80 per cent. phosphorus.

14 per cent. Missouri pig iron.

15 per cent. old rolls, grate bars, car couplers, and other cast scrap.

46 per cent. malleable scrap, black plate bundles (scrap from the tin-plate works), old rails, burnt annealing boxes, agricultural scrap and wrought scrap of any description

* *Iron Age,* vol. vii. pp. 919–920, with illustrations.

The melting loss averages 5 per cent. It requires about 800 pounds of Iron Mountain hæmatite ore, containing 65 per cent. of metallic iron and 4 per cent. of silica, to finish a heat. Limestone from Louisiana, Missouri, is charged raw in quantities of from 5 to 10 per cent. of the total charge. Only for finishing the heats burnt lime is used. The weekly averages of slag show the following composition :—

	When Running on	
	First Quality.	Second Quality.
Silica	14·85	23·70
Alumina	0·40	0·88
Phosphoric acid	2·69	7·90
Ferrous oxide	13·50	6·17
Ferric oxide	5·36	3·36
Manganese oxide	2·78	4·09
Calcium sulphide	0·22	0·17
Lime	54·80	45·52
Magnesia	4·77	7·71
Totals . . .	99·37	99·50

Dolomite without admixture of binding material is used for the bottom and tap-hole, and is calcined in the same furnace which serves for calcining lime and also for heating pig iron and ferromanganese. Analyses of limestone and dolomite and magnesia bricks for the lower parts of the hearths are as follows :—

	Limestone.	Dolomite.		Magnesia Bricks.
Silica	0·34	0·73	5·52	2·32
Alumina and oxide of iron .	0·39	1·12	3·74	1·24
Lime	55·44	29·48	29·20	3·98
Manganese	trace	20·26	17·31	92·59
Loss on ignition . . .	43·69	48·23	43·82	...

No neutral zone is found necessary between the silica bricks and the basic lining. The gas-producers are oval in section, 7 by 9 feet and 12 feet high. The gas made contains :—

CO_2.	O.	CO.	H.	Hydrocarbons.	N.
3·6	0·1	25·8	9·0 to 15·0	3·9	51·0 to 57·0

Five producers give sufficient gas for the three furnaces and for two four-hole soaking pits. Each producer can convert 15 tons of coal in twenty-four hours, and about 1300 to 1400 lbs. of coal are used per ton of steel made. The coal shows on assay :—

Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
4·83	36·12	54·41	4·64	1·03

Chemistry of the Open-Hearth Furnace.—In a paper read before the West of Scotland Iron and Steel Institute, A. M. Dick and C. S. Padley * treat the subject in a more or less elementary form, confining themselves to some of the chief reactions already well known to metallurgists.

B. Dawson † fully discusses the recent progress in open-hearth steel-making.

Charging Appliance for Open-Hearths.—W. Schmidhammer ‡ describes charging appliances. He observes that they possess manifest advantages, but the cramped space in many of the older furnace plants rendered their use quite impracticable. In 1889 the author went to Witkowitz to study the charging apparatus which had then been recently placed in work there. This was in principle similar to the one referred to in another abstract in this volume, but with the difference that the lever bar could not be raised, and the vertical movement of the more recent Lauchhammer appliance is a great improvement. The author, after inspecting the Witkowitz machine, came to the conclusion that while such an apparatus might do for a number of furnaces in line, yet that it took up too much space and was too costly for use in the case of small plants with one or two furnaces. The author proceeded to devise a machine suitable for such a case, as in his works he had but two furnaces to arrange for. He abandoned the trough shape, and adopted a series of shovel-pans of the dimensions of 23·6 and 31·5 inches broad by 39·3 inches in length, which were cast on to the bottom of a four-cornered conical shell. Midway in front of the two furnaces was placed a hydraulic crane of 2½ tons capacity, the beam of which could reach to the middle door of each furnace. To this crane the lever bar was attached by means of a chain connection, and it in turn bore the shovel attachment. The lever bar could readily be kept horizontal by four men when weighted with 0·6 ton of pig iron, more men being required for this purpose when charges of greater weight were made. When the material to be charged was of such a character that the charge weighed at least 0·6 ton, then 15 tons, that is to say, twenty-five shovel loads, could be charged into the furnace in from thirty to thirty-five minutes. If the material to be charged is very voluminous in character, a cubic metre often weighing less than 0·3 ton, then the

* *Colliery Guardian*, vol. lxxi. p. 320.

† *Iron and Coal Trades Review*, vol. lii. pp. 158–159.

‡ *Stahl und Eisen*, vol. xvi. p. 14.

advantage to be otherwise gained by the use of such a machine ceases, and hand-charging is just as quick. The best way to deal with very voluminous material like this would be to "packet" it, compressing it to a smaller bulk, if this could be done at a sufficiently low cost. A machine such as that just described possesses the important advantage over the larger charging appliances in that it is much more simple and correspondingly cheaper. It may quite well be used for single furnaces, while the use of the larger apparatus would not pay under these conditions, and it may, too, be employed for older plants where the space available is cramped in character.

The Casting of Steel.—According to S. Kern,* at the Obouchoff Steelworks, St. Petersburg, great inconvenience was felt for a long time in casting large round ingots of five tons and upwards for forging guns. The stream of steel falling from a considerable height into the mould from the 30-ton ladles of the open-hearth furnaces gives rise to a considerable quantity of splashes, which produce cracks on the surface of the ingots. The same annoyance was also observed in casting rectangular ingots of 25 to 30 tons for armour plates. M. Posnikoff, the manager of the steel department of these works, has devised a very simple method of preventing the steel from splashing.

A tube is prepared of thin sheet-iron, such as is used for roofing. The tube is 24 inches in inside diameter, and is suspended from an iron ring, to which there are riveted three bars on the surface of the mould just before casting. The steel is poured from the bottom of the ladle into the middle of the iron tube. All the splashes are thrown on the walls of the tube, which gradually melts away during the rise of the surface of the liquid steel in the mould.

According to H. M. Howe,† the method devised by Posnikoff of preventing the spattering of steel against the sides of the moulds by putting a thin sheet-iron tube within the mould through which the steel was poured was really anticipated by A. L. Holley's practice at the Bessemer Steelworks at Troy, New York, in 1871. A like trouble occurred there, not, however, so much from the metal splashing up from the bottom of the mould against the sides, as from irregularity in the shape of the nozzle at the bottom of the casting-ladle, which made the falling stream of steel irregular and ragged. It often happened that the drops

* *Chemical News*, vol. lxxiii. p. 88.
† *Engineering and Mining Journal*, vol. lxi. p. 395.

of steel would in this way spatter against the sides of the mould, and adhering to them, roughen the face of the ingot. To prevent this, Holley suspended in the mould a cylinder of thin sheet-iron, through which the steel was poured, and which melted off as the level of the steel rose past it. The practice was not continued, because it was found that the cracking of the ingots in rolling (which had been supposed to be due to this spattering) continued unabated after the spattering had thus been arrested.

External Faults in Ingots.—According to Odelstjerna,* cracks and other external faults in ingots are largely due to casting in old moulds. These contain air-filled pores, and the enclosed air expands and forces itself into the thin solidified skin of the steel. Those ingots have the best surface which are obtained when the metal is allowed to rise upwards in the moulds, and when the whole charge is tapped away at one time. The contraction cracks at the lower ends of the ingots are avoided in this way, and these are especially dangerous, because their presence only becomes evident in the finished products. There is no other possible method of avoiding external blowholes than by the adoption of a suitable temperature in casting, or the use of aluminium or silicon additions to the charge.

Reversing Valve for Open - Hearth Furnaces.—Illustrations have been published of a valve designed by J. R. Wright and W. Veitch,† to overcome the constant leakage and trouble arising from the use of circular and square tongue valves in regenerative furnaces. The appliance comprises an outer casing, within which is a movable valve in the form of a box; this is actuated by levers or cranks, and is large enough to cover one gas opening and the opening to the chimney flue. It has its bottom edges embedded in sand, water, and other material, which makes a gas-tight joint. There is ample room in the channel that contains the material forming the bed or seating for any warping that may take place through the heat of the return gases. The bed or seating can be renewed at any time when the furnace is working by unskilled labour. Another advantage is that the full area of the openings is available. The valve illustrated was employed in a 12-ton Siemens melting furnace.

* *Berg- und Hüttenmännische Zeitung*, vol. liv. p. 420.
† *Engineering*, vol. lxi. p. 689.

Steel Plant at Middlesborough, Kentucky.—C. R. Boyd [*]
states that a steel and iron plant at Middlesborough, in Kentucky,
possesses two blast-furnaces 75 by 17 feet, seven open-hearth furnaces
of the Batho type, and a 32-inch mill for blooms and billets. The blast-
furnace plant has seven Whitworth stoves 60 by 20 feet, six blowing
engines with 36-inch steam cylinders, 84-inch air cylinders, and 6-foot
stroke. The steel plant is 1000 feet north of the blast-furnaces. The
mill is placed at right angles to the building containing the open-hearth
furnaces. Twenty-four producers supply gas. There are five 5-ton
hydraulic cranes, two soaking-pits capable of holding five ingots to each
of their four holes. The mill rolls 4 by 4 inch billets or slabs 16 inches
wide, and is driven by reversing engines with 34-inch cylinders and 5-feet
stroke. Guillotine shears are provided to cut up to 8 by 8 inches.
Rollers at the shears and mills are power driven. The pig iron used
and steel made analysed as follows :—

	Carbon.	Phosphorus.	Sulphur.	Silicon.	Manganese.
Pig iron . .	3·23	0·975	0·097	1·15	...
Steel . . .	0·09	0·024	0·001	0·01	0·466

The furnaces are lined with dolomite of good quality from the neigh-
bourhood. The furnace now in blast produces 170 tons daily of the
following composition :—

Silicon.	Sulphur.	Phosphorus.	Graphite.	Combined Carbon.
1·631	0·612	0·250	2·44	0·329

An Early Open-Hearth Furnace.—S. T. Wellman [†] describes and
illustrates fully an open-hearth steel furnace designed and built by him-
self at South Boston for the Bay State Iron Works in 1867. It was
intended for making the steel for the manufacture of steel-headed rails,
but these were not practically successful. The design is similar to those
now used, but at the present day thicker division walls between the
ports are used, the gas ports are covered, and a higher roof is generally
used. The charge was five tons, and two heats were made in the
twenty-four hours.

Chinese Government Steelworks. — G. Toppe,[‡] the general
manager of the iron and steel works at Han-Yang belonging to the
Chinese Government, describes the works under his direction. Han-

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[*] *Iron Age*, vol. lvi. pp. 1166–1167.
[†] *Ibid.*, vol. lvii. pp. 13–14.
[‡] *Stahl und Eisen*, vol. xvi. pp. 141–143.

Yang is the chief town of the province of Hu-Peh, and lies at the junction of the Han-Kiang with the Yang-tse-Kiang, near the town of Hankow. The steelworks lie in a depression which was formerly a part of the bed of the river. To allow the water to drain away, it was therefore necessary to raise the floor of the works about 12 feet, and a dam of the same height has been erected all round the works to prevent damage from floods from the Han or Yang-tse. The works comprise a blast-furnace plant and laboratory, puddling furnaces and a rolling-mill plant, a Bessemer shop and an open-hearth plant, together with rail-mills, machine shops, and railway shops and shipbuilding yard. At the head of each section is a European, and the foremen and principal workmen are also Europeans, the total amounting to thirty-four. The blast-furnace plant comprises two blast-furnaces, each 64 feet in height and 7·4 feet in diameter. Each furnace is served by three Cowper stoves, 54 feet in height and 19·7 in diameter. Two other stoves and a larger horizontal blowing-engine will be erected should both furnaces be put into blast.

No. 1 blast-furnace was blown in a second time on 16th September 1895, having been in blast for about six months in the previous year, but then shut down owing to the absence of an adequate supply of coke. The coke available is of very poor quality, containing about 25 per cent. of ash. Using this coke, the production of the furnace amounts to about 60 tons in the twenty-four hours. With good coke it would probably amount to from 75 to 80 tons. There are twenty single puddling furnaces erected. These are of the usual size, and are built in groups of four, the waste gas from which heats a vertical boiler. Seven of the furnaces are at work at the present time. Each of these makes in the shift of twelve hours six 5-cwt. charges. The blooms are treated under two 3-ton steam-hammers, and are sent through a train of roughing rolls of 20 inches diameter. The sheet-mills are no longer adequate for the works, and a larger engine is to be erected. There are two 5-ton Bessemer converters, but the present blowing-engine plant is now inadequate, and a blowing-engine of larger size is to be erected. The works possess one 12-ton open-hearth of ordinary construction, served by four Wilson producers. The rail-mills and foundry are also described, the latter being provided with three cupolas and a 20-ton travelling crane. The machine shops and other parts of the plant are also briefly referred to. A plant for the manufacture of firebricks is in course of erection.

Coal is obtained from the district of Ma-ngan-shan, two days' journey from the works, and iron ore from Government mines in the Tajeh

district. The coal from Ma-ngan-shan is not in itself suitable for the manufacture of furnace coke, and for this purpose it has to be mixed with coal from the Hunan district. The resulting coke is high both in ash and in sulphur, the latter not being greatly reducible by washing. The coke made by the Chinese in the Hunan district, by coking in small pits about a yard by 2 feet in section, is of much better quality. A very excellent coke is made from the coal of the Kaiping collieries, near Tientsin; while Japanese coke, though otherwise of good quality, contains a good deal of sulphur. The following are the approximate contents of the various varieties of coke above referred to :—

Coke.					Phosphorus.	Sulphur.	Ash.
					Per Cent.	Per Cent.	Per Cent.
Ma-ngan-shan	.	.	.	.	0·03	5·0	25
Hunan .	.	.	.	.	0·07	0·7	18
Hunan .	.	.	.	.	0·01	1·3	13
Kaiping .	.	.	.	.	0·05	0·8	15
Japanese	.	.	.	.	0·02	2·8	20

The Government Ma-ngan-shan colliery cannot now produce one-half the coke that is required at the works, and it is probable that a large coal-washing and coking plant may be erected at the ironworks themselves to treat the coal, which is there readily obtainable. It would then be possible to produce a coke of the same quality as that of Hunan. A battery of Coppée ovens has already been erected for this purpose.

The Tieh-Shan (Iron Mountain), in the Tajeh district, from which the ore is now obtained, has probably long been worked. It is connected by a short line of railway with the Yang-tse. The ore mined is magnetic, the percentage of phosphorus being higher in the ore at the foot of the mountain than in that near the summit. On an adjoining hill a very pure limestone is obtainable, and wide veins of brown iron ore are also mined. Other mountains of the range are also rich in ores of excellent quality. Besides brown iron ore high in manganese, there is a manganese ore which is mined near Chin-kon-chan. The following are average analyses of large quantities of ore :—

Ore.			SiO_2.	Al_2O_3.	Fe.	Mn.	P.	S.
Magnetite, Tieh-Shan	.	.	3·1	0·6	64·4	0 2	0·15	0·10
Magnetite, Tieh-Shan	.	.	4·6	1·6	63·5	0·2	0·06	0·10
Magnetite, Tieh-Shan	.	.	4·3	2·1	63·0	0·2	0·04	0·10
Brown iron ore	.	.	9·0	2·5	45·5	6·5	0·03	0 05
Brown iron ore	.	.	7·3	3·2	45·0	8·7	0·03	0·04

An old slag which is also smelted contains—

SiO₂.	Al₂O₃.	CaO.	MgO.	Fe.	Mn.	P.	S.
21·8	1·1	0·6	0·5	52·2	0·25	0·125	0·031

The author observes that both ore and coal are found in inexhaustible quantities, and he looks forward to the manufacture at the works of iron and steel of the best qualities, and on a very large scale. The whole of the works, he anticipated, would be in regular work within three or four months from the date at which he wrote.

Steelworks.—A detailed description has been published * of the Parkhead Forge, Rolling Mills, and Steelworks. The paper is accompanied by illustrations of a lathe engaged in cutting a 64-ton nickel steel cylinder for a 12,000-ton hydraulic forging press, the cogging-mill and hot bloom shears, reversing rolling-mill engines, 100-ton travelling crane for serving forging press, Harveyed steel casemate, 6 inches thick, for H.M.S. *Terrible,* planing machine, crank shaft of H.M.S. *Powerful,* and lathe with 69-inch centres.

A description has also been published of an exceptionally fine platemill recently added to the Plant of the Patent Shaft and Axle Tree Company at Wednesbury.†

Illustrations have also been published of one of two pairs of geared rolling-mill engines constructed for the new steelworks of the Dowlais Company.‡

At the Saint-Etienne Steelworks there are two 25-ton open-hearths, as well as others of 15 and of 7 tons capacity. The two large furnaces are tapped into a common receptacle which will hold 65 tons, and thence the metal goes to a casting ladle of considerable size placed in a pit nearly 30 feet deep. Without difficulty castings of from 60 to 70 tons can readily be made, as in addition to the metal from the two larger furnaces the necessary additional quantity can be obtained from the smaller furnaces by the aid of two travelling cranes which command the whole works.

Electricity is very largely used as a source of power, and when complete this portion of the plant will include a horizontal 250 to 300 horse-power Wheelock engine and two dynamos coupled in series, each capable of yielding a current of 650 amperes and 110 volts. The casting house and rolling mills are also described, together with the methods of

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* *Engineer,* vol. lxxxi. pp. 130-131, 153-155.
† *Ibid.,* p. 330.   ‡ *Ibid.,* p. 375.

mechanical tests which are in use, automatic methods of registration being adopted.*

Illustrated descriptions have also appeared of the Latrobe Steelworks,† Pittsburgh, United States; of the works of Boel Brothers,‡ La Louvière, Belgium; of the Homestead Steelworks, United States;§ of Consett Steelworks;‖ of the works of the Johnson Company, Lorain, Ohio;¶ of the works of the Ohio Steel Company at Youngstown;** of the Seraing works of the Cockerill Company, Belgium;†† of the Lackawanna Steel works.‡‡

Sulphur in Steel.—F. E. Thomson §§ deals at some length with the problem of sulphur removal from steel. At present the basic process is the best solution, but it may be said that the removal of sulphur from iron under the influence of a lively slag is merely a coincidence. There is no widely used process which aims at the complete elimination of sulphur, but a better knowledge of the reactions between sulphur and lime, manganese and oxide of iron, may bring the solution nearer. Within the limits which sulphur occurs in practice it may be said to be harmless, but it would be of great advantage if high sulphur stock could be used. From existing literature on sulphur elimination, four laws may be deduced: (1) sulphur is not usually appreciably diminished in the acid converter or furnace; (2) sulphur may be in part removed from pig iron in the basic converter or furnace. The elimination is greatest in high sulphur stock, and is greatly influenced by many independent conditions; (3) sulphur elimination is promoted by presence of manganese, and by agitation or contact of molten metal with calcium bases or oxide of iron; (4) sulphur in basic steel is generally reduced by the addition of manganiferous recarburizers.

Sulphur in ordinary mild steel runs between 0·03 and 0·08, and any misbehaviour is seldom traced to this element. In fire-box steel the sulphur must be much lower, as its effect cannot be masked by the presence of much manganese. Such soft steel may be produced free from manganese and sulphur by selecting the stock, which may be somewhat more sulphureous if the basic process is used. By overblowing,

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. pp. 697–699.
† *Engineering*, vol. lxi. pp. 571, 642.
‡ *Iron and Coal Trades Review*, vol. lii. p. 841.
§ *Ibid.*, vol. lii. p. 10.   ‖ *Ibid.*, p. 149.
¶ *Ibid.*, p. 152.   ** *Ibid.*, p. 153.
†† *Ibid.*, p. 153.   ‡‡ *Ibid.*, p. 481.
§§ *Iron Age*, vol. lvii. pp. 810–814.

sulphur is sometimes, but not always, reduced. The author, in sixty-four high sulphur basic Bessemer blows, has not found that 0·100 to 0·193 per cent. of sulphur caused the steel to differ from the ordinary run, as far as tensile tests and finished plates were concerned, and he cannot trace V-shaped cracks produced during rolling to this element. Of these sixty-four blows, seven were greatly or considerably red short, and thirty-four entirely free from red shortness. This is probably accounted for by the 0·3 to 0·5 per cent. of manganese present, but in lower manganese steels less sulphur caused red shortness. If it is below 0·2 the sulphur must fall below 0·05. Turning then to sulphur in the basic open-hearth furnace, the author shows that the additions of ore have some effect on the elimination, and his figures tend to bear out the mechanical theory. Time has also some effect in reducing the quantity, and more sulphureous irons, of course, show a greater percentage reduction. The most marked effect is given by lime additions to the molten slag. Fluorspar does not seem to have much effect, except to chill the bath. The author then gives very full details of four heats in which the prevailing additions were ferro-manganese, fluorspar, manganese ore, and excess of lime. These include the time and weight of each addition, and a complete analysis of both slag and metal before each addition. As far as sulphur elimination was concerned, the results were a failure, so next special methods of charging were adopted, and of these again similar details are given. The results were variable, and the author concludes that neither special additions nor special arrangements of the charge yield any lower sulphurs than those which are obtained as the ordinary results of good practice. As indicated above, very numerous and complete analyses are given in this account.

III.—*THE BESSEMER PROCESS.*

The Walrand-Legenisel Process.—H. L. Hollis * gives the latest particulars of the Walrand-Legenisel process which was described by G. J. Snelus † in 1894. The vessels employed are the usual type of bottom-blown Bessemer converters. They receive the pig iron in the usual way, and are blown until the flame drops, when they are turned

* *Transactions of the American Institute of Mining Engineers.* Pittsburgh Meeting.
† *Journal of the Iron and Steel Institute,* 1894, No. I. p. 26.

down, and ferro-silicon, with 10 to 12 per cent. of silicon, is added. After an afterblow, ferro-manganese or spiegel is added and the metal poured into large or small ladles. In one instance not less than twenty minutes was taken for casting, but no skull formed in the ladles. Blowing is generally controlled by the spectroscope. At the Paris Works of E. Legenisel there are two converters of 1200 and 600 lbs. capacity. All the steel scrap, amounting to about 20 per cent. of the charge, is melted in the cupola with the pig iron. Additions are melted in a small and ingenious cupola, and are transferred by ladles. In blowing the converter is turned down just before the drop, so as to leave enough carbon to act as an index in the spectrum in the afterblow. Silicon seldom exceeds 0·05 per cent., and often runs as low as 0·02. A very large part of the work is cast in green sand. At the Le Creusot Works there is one 1500 lb. converter. Steel scrap is added directly, and ferro-silicon and spiegel are added red-hot, not molten. The spectroscope is used, and the vessel is turned down earlier in the afterblow, so as to leave more silicon. At Hagen, Westphalia, there are two 1200 lb. vessels. Blowing is continued until the drop, and the afterblow is controlled by time and by the appearance of the flame. Additions are melted in crucibles, and small work poured from crucibles. The Potter Hollis Company at Chicago has one 1500 lb. converter, and is adding another. Steel scrap is run through the cupola, and additions are made in the molten state. Blowing is controlled as in Paris, but the blast pressure is only about 10 lbs. as compared with 30 lbs. on the Continent. Pin bottoms and also the usual tuyere bottoms are used.

The steel made is satisfactory in every respect, and sound castings of any size and ingots are obtained. Carbon, manganese, and silicon are entirely under control, the first two by additions and the latter by blowing. Phosphorus and sulphur depend on the stock. Uniformity is obtainable, and at Chicago the usual run of castings shows :—

Carbon.	Silicon.	Manganese.
0·25 to 0·30	0·10 to 0·20	about 0·60

This steel gives the following tests :—   .

	Tensile Strength. Lbs. per Square Inch.	Elongation on 8 Inches. Per Cent.
Unannealed . .	. 75,000 to 80,000	5
Annealed . .	. 70,000 ,, 75,000	12

The usual practice is reversed, as the hotter the steel the more solid and more satisfactory are the castings. Silicon may regularly be reduced as low as 0·05 per cent., but nothing is gained in the castings, whilst by

increasing it even as high as 0·50 per cent., the tensile strength is raised without appreciably lowering the elongation. A number of heats with this process have been blown in 8-ton vessels at Les Acieries de France to obtain soft steel for wire. The product showed below 0·02 per cent. silicon, 0·13 carbon, and 0·20 manganese, with 50,000 lbs. tensile strength and 27 per cent. elongation. The author then summarises the advantages. It furnishes a steel foundry with fluid quiet steel in such quantities and at such intervals as are best adapted for the work. Small and intricate pieces can be cast, and green sand moulds may be used, as the steel remains fluid, so that it can be poured quietly over a lip. For subsequent machining dry sand moulds are preferred. The cost of plant is relatively small, and the converter can be fitted up in an hour, so that continuous work is not altogether necessary. The author adds that Walrand claims the same results in the basic process by substituting a high phosphorus iron for the ferro-silicon additions.

At the Franco-Russian Works, St. Petersburg, this process was lately started with good success by the inventors. S. Kern * describes five blows, consecutively made, in one afternoon. The converter is designed for a charge of 660 lbs., and is run from a Walrand cupola, working very regularly. The charge consists of Ayresome pig iron, scrap (runners, top-ends, &c.), and a small quantity of ferro-silicon, in order to have in all 3 to 3·15 per cent. of silicon in the metal to be converted into steel. During the third period of the blow a charge of ferro-silicon was added, an afterblow made, and, finally, silico-spiegel added. The resulting steel is poured into ladles, into which about 0·1 per cent. of metallic aluminium is thrown. The steel is hot and readily fills the mouldings. The metal in the castings is soft and ductile. The following notes give an idea of the *modus operandi* :—

First blow commenced at 1.51 P.M. ; metal from fourth blow poured into moulds at 4.5 P.M. So that in two hours fourteen minutes four blows were made.

Description of the first blow, which was the coldest of all, being the commencement of operations :—

1. Pig iron poured into the converter, and blow commenced at 1.51 P.M. (pressure of air about 32 lbs.).

2. Commencement of the second period, line D. of sodium well marked, 2.2 P.M. (pressure of air about 15 lbs.).

3. Converter turned to add ferro-silicon, and commencement of afterblow at 2.8½ P.M. (pressure of air 22 to 24 lbs.).

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* *Chemical News*, vol. lxxiii. pp. 111–112.

4. Silico-spiegel added at 2.10½ P.M.

5. Commencement of the pouring of steel into ladles, 2.14 P.M.

The same process, but with two (nearly one ton each) converters, has been started also at the Baltic Shipbuilding Works, St. Petersburg, and with encouraging success.

For small castings up to 100 to 150 kilogrammes, crucible steel appears more suitable, being a little colder, with less gases in solution, and therefore quieter. It fills better the small mouldings attached to a general runner. The new process appears to be specially well adapted to large and medium-sized castings.

The Cambier Converter.—J. Smeysters [*] describes a small converter with side blast adopted at the works of E. Cambier at Charleroi. Having a capacity of 1½ to 2 tons, this converter is supplied with side blast, not by tuyeres, but by circular apertures carefully arranged in the refractory masonry of the lining. These apertures, of which there are seven, dip at an angle of 12°. The air is admitted at a pressure of 0·4 to 0·6 millimetre of mercury, and the duration of a blow does not exceed ten to twelve minutes.

The Tropenas Steel Process.—A few particulars of the Tropenas steel process have recently appeared.[†] The converter is shaped to give greater depth to the bath, and the tuyeres are placed on one side in two rows, independently supplied with air, and blow on to the surface of the metal. Various advantages are claimed, and the product is stated to be hot and uniform, and to be adapted for making small castings.

Pig Iron Mixers.—A. Knaff[‡] observes that very little has been as yet written as to the results obtained in practice with pig iron mixers. It was in 1889 that the first of such mixing plants was laid down for basic Bessemer pig iron at the Hörde Works. One of the points most open to question at the time was whether the iron charged into the mixer from the blast-furnace was subject to any important loss of temperature during the time it remained in the mixer prior to its further treatment. It was soon found, however, that no very marked loss of heat resulted, as the substances which separate from the iron, notably manganese sulphide, evolve considerable quantities of heat by combina-

* *Annales des Mines de Belgique*, vol. i. pp. 97–100, with three illustrations.

† *American Manufacturer*, vol. lviii. p. 441.

‡ *Stahl und Eisen*, vol. xvi. pp. 100–102.

tion and oxidation. These include the oxidation of sulphur and of manganese, and the conversion of the manganous oxide into the silicate. In the Hörde Works the influence of the silicon and lead present on this increase of temperature is found to be unimportant. The metal only contains as a rule about 0·20 of silicon, while a little lead, derived from imported ore, is also noticed. As evidence of oxidation of lead in the mixer the author detected a white deposit, which he found to have the percentage composition shown below :—

PbO.	SO₃.	Fe₂O₃.	Mn₃O₄.	Cl.	CaO + MgO.
59·07	32·58	8·00	0·93	0·15	traces

The desulphurisation in the mixer results from the combination of the manganese and the sulphur in the pig iron under treatment. Forty-five per cent. of the sulphur it is found is eliminated in this way. The oxidation of the manganese results in a considerable evolution of heat, and causes the mixer lining to be corroded along the slag line. The following are analyses of mixer slags at the Hörde Works showing this action :—

	Slag close to the Iron.	Upper Part of Slag.
	Per Cent.	Per Cent.
Silica	24·20	29·70
Manganous oxide	45·20	40·84
Sulphur	9·81	7·99
Iron	6·01	5·31

The lining of one of the mixers was reduced in thickness at the slag line from 350 millimetres to 170 millimetres in three weeks. The joints between the bricks were attacked the most seriously. In renewing, the lining bricks above referred to were replaced by others of twice the size, but the corroding action remained unchanged. The bricks and mortar used had the composition :—

	SiO₂.	Al₂O₃.	Fe₂O₃.	CaO.	MgO.
Bricks . .	60·50	37·66	2·00	0·57	0·22
Mortar . .	64·34	31·20	3·06	0·65	0·28

The frequent repairs along the slag line caused the roof to suffer, and this required frequent repairs as well, especially in the vicinity of the funnel. The cost consequently was considerably increased, and it became necessary to find some remedy. Magnesite bricks were experimented with in 1893 at the suggestion of G. Hilgenstock, and their use

in the neighbourhood of the slag line was so successful that the mixer could be used continuously for several months. Finally, the whole of the mixer, except a portion of the roof, was lined with magnesite bricks, and could then be used for about nine months continuously, without any except a few very slight repairs. The cost of lining with magnesite at Hörde amounted to 1806·55 marks (about £90), but a saving in labour was the result. In 1893, when 145,131 tons of metal were put through the mixer, an acid lining being used, the wages paid for repairing amounted to above £82; while in 1894, 155,964 tons were treated on a basic lining for less than £42. The author gives illustrations of the mixer as erected at Hörde, and he describes the method of lining that is employed. Various difficulties which have been experienced in using the magnesite linings are also referred to. The larger the size of the bricks the better they are, but practical difficulties in their manufacture limit the maximum attainable size of the bricks. The shapes and dimensions of the magnesite bricks used at the Hörde Works are given, the warming up of the freshly lined mixer is described, and details are given as to its subsequent working and the points which are to be observed. The removal of cold slag and metal from the surface of the molten metal before running out the charge is referred to. A cake of solidified slag on the surface of the metal not only directly absorbs heat, but, by preventing atmospheric action, stops oxidation, and so prevents any reheating of the metal by the oxidation of the foreign elements it contains. The manganese sulphide that separates from the metal collects beneath any solidified slag covering and solidifies gradually, without oxidation, being then useless as a source of heat. Experiments with dolomite in the place of magnesite have so far not been made at Hörde. The questions of the best shapes and sizes to be given to pig iron mixers are also briefly referred to.

Loss of Metal in the Basic Bessemer Process.—It is pointed out by Grassmann * that the loss of metal in the conversion of pig iron into ingot metal is so considerable that it is remarkable that the literature on this subject is so small. The statements that are made as to this vary between somewhat wide limits. Thus at some works the loss reaches 17 per cent., while others state with pride that at their works this loss only amounts to 13½ per cent. in the basic Bessemer process. At some of the more modern works, however, this loss has been reduced to 11 per cent. of the iron charged. This difference in the loss is too considerable for

* *Stahl und Eisen*, vol. xvi. pp. 57-61.

the explanation to lie in any great difference in the metallurgical processes employed, as these, after all, are not very different at any of the works. Other conditions must therefore come into effect, and doubtless the variation in the quality of the pig iron used must play a much greater part in this than is usually accepted. With a yearly outturn of 200,000 tons of ingot metal, the reduction in the loss of metal from 16 to 11 per cent. would mean a saving of about £35,000.

Turning to the question of the composition of the pig iron used, the author observes that for the basic process the following has been found the most satisfactory :—

Phosphorus.	Manganese.	Silicon.	Carbon.
1·90 to 2·70	1·10 to 2·00	0·20 to 0·50	3·20 to 3·60

or from 6·40 to 8·80 per cent. in all. If then only these elements were eliminated from the pig iron in its conversion into ingot metal, without other loss, the total loss on the original weight of metal charged would be from 6·40 to 8·80 per cent. In actual practice, however, as has just been shown, this loss commonly varies from 13 to 17 per cent., twice as great, that is, as it should be in the theoretically perfect process. Considering the sources of this loss, the author points out three :—(1) from the elimination of the foreign elements in the pig iron, (2) the loss of iron during the oxidation of these foreign elements, and (3) the mechanical loss of metal during the blow. With regard to the first of these, the lowest permissible percentage of phosphorus has in practice been found to be 1·90, and that of silicon 0·20, and the total non-preventible loss must approximate as stated to from 6·40 to 8·80. The second source of loss, due to a simultaneous oxidation of the iron during the elimination of the foreign impurities, varies with the varying conditions of the blow. It is mainly dependent on the temperature of the blow, and on the relative basicity of the slag. The percentage of iron in basic slag usually varies from 6 to 14, the iron being mainly present as magnetic oxide. This ferruginous slag is only formed towards the end of the process, during the afterblow. The loss of metal from this second source is due then to the afterblow, and it varies with the quantity of the slag produced. This approximates to 25 per cent. of the weight of the iron charged, and as it contains from 6 to 14 per cent. of iron, the total loss of metal due to the afterblow is from 1½ to 2½ per cent. The author suggests that the addition of an equivalent quantity of iron oxide to the slag during the afterblow would eliminate this source of loss. That it is actually possible to reduce the loss of iron to a minimum by the addition

of high-percentage ore during the afterblow, the following results show. These are taken from the results of a large number of basic blows :—

Meta Charged.	Ore Added.	Steel Made	Loss	Composition of Slag.		Temperature of Blow, Loss, and Blow Out.
				Phosphoric Anhydride.	Iron.	
Tons.	Ton.	Tons.	Per Cent.	Per Cent.	Per Cent.	
12·0	nil.	10·35	13·75	24·60	10·58	Hot, but little.
12·6	nil.	11·03	12·46	23·45	9·85	Warm ,, ,,
11·5	0·20	10·35	10·00	21·91	8·06	,, ,, ,,
11·5	0·25	10·15	11·74	22·87	12·26	Hot, average quantity.
13·0	0·25	11·65	10·38	24·51	10·28	Hot, but little.
11·6	0·40	10·45	9·13	22·90	12·60	Hot, none.
11·5	0·40	10·50	8·88	23·80	7·62	Warm, none.
11·1	0·50	10·14	8·63	23·60	10·70	,, ,,
13·0	0·40	11·98	7·84	24·30	4·20	Very quiet, none.
14·0	nil.	12·30	12·14	21·40	9·76	,, ,,
12·3	nil.	10·64	13·49	20·90	11·45	Quiet, but little.

A number of other results are given in addition to the above.

With regard to the question of the mechanical loss during the blow, this amounts to about 5 per cent. There is no theoretical justification for this loss, which depends on the shape and size of the converters, on the chemical composition of the pig iron, and on its physical character, dependent on this composition. By increasing the size of the converter, the loss of metal blown out of the converter is reduced to a minimum; but this would bring about other disadvantages. A suitable chemical composition for the pig iron is a better means of preventing this loss. If the melting-point of the metal is higher, and the metal itself when molten is thick fluid, the loss of metal blown out of the converter is evidently likely to be higher than when a thin fluid metal of low melting-point is being blown. The presence of silicon in the metal helps to render it thin-fluid, but too much silicon is a disadvantage to the process. Manganese exerts a similar effect. One per cent. of manganese will ensure that degree of fluidity in the metal which always makes the manganiferous character of pig iron so apparent when the metal is flowing from the blast-furnace. If pig iron, too low in manganese, is blown in a converter, the loss of metal blown out of the converter is always very large, and the process itself an economical failure. Phosphorus exerts a similar fluidifying influence on the molten metal, and it lowers the melting-point of the iron very considerably. The more phosphorus there is in the iron, the quieter will the blow be. The author shows by a series of results the influence exerted by

varying the percentage of phosphorus on the loss of metal during the blow. The following are some of these results :—

Composition of Pig Iron per Cent.			Total Loss of Metal per Cent.
Silicon.	Manganese.	Phosphorus.	
0·31	1·10	3·23	10·9
0·60	1·70	3·22	11·8
0·60	1·59	3·00	12·8
0·60	1·63	2·79	13·9
0·60	1·66	2·36	17·8
0·59	1·30	2·12	20·5

The author plots his results graphically, showing that the loss of metal varies regularly with the percentages of silicon and of phosphorus. With increasing percentages of silicon there is an increasing percentage · of loss ; but in the case of phosphorus the result is the reverse, the loss of metal diminishing as the percentage of phosphorus increases. It is, therefore, in the interests of basic works, the author points out, to work with pig iron as high as possible in phosphorus, any difficulties that might be experienced owing to the blows being too hot, being likely to be got over very readily by any works manager.

Regulating the Duration of the Afterblow.—A. Brovot * describes a method of regulating the duration of the afterblow in the basic Bessemer process.

It having been found that the percentages of iron contained in basic Bessemer slag was a variable quantity, it was considered desirable to reduce the percentage to as low a minimum as was compatible with an adequate dephosphorisation of the charges, and in endeavouring to bring this about the process was developed which the author now describes. It consists in blowing some charges in the ordinary way, and ascertaining after each blow the analysis of the metal and the analysis of the slag as regards iron contents. The tests are compared with each other, and the percentages of iron in the slag are noted. It will be found that they vary greatly. That slag which contained least iron being considered as representing the most satisfactory blow, the metal of course being of satisfactory quality, an effort is next made to obtain a similar or better slag in the succeeding blows by gradually reducing the duration of the blow. It is not an easy thing, even for those most skilled in the work,

* *Stahl und Eisen*, vol. xvi. pp. 50–57.

to decide exactly what extra duration of blow is necessary by aid of the ordinary tests. The changing composition of the metal in the converter and the variations in the progress of the blow induced by them may readily deceive any one. Care should be taken always to ascertain the percentage of manganese contained in the iron charged into the converter. This knowledge is of importance in connection with the heat of the blow, and also in that if the percentage of manganese is too high it is necessary to continue the afterblow for a longer period in order to reduce the phosphorus to the desired minimum. Perhaps the best percentage of manganese in the converter charge is from 0·6 to 0·85. In converting direct metal care must be taken that the percentage of sulphur it contains does not exceed 0·1, while that of silicon must also be as low as possible. It is a common error, especially in hot blows, to continue the afterblow for too long a period. This leads to a much larger percentage of iron passing into the slag, and induces the conditions which result in a rephosphorising of the metal from the slag during the recarburising period, some of the phosphate being reduced as well as the iron, with the formation of iron phosphide which passes as such into the metal under treatment. The customary endeavour, to ensure the complete elimination of the phosphorus by increasing the length of the afterblow may lead to an entirely opposite result. The common assumption, therefore, that the blow was stopped at the right moment by doing so directly the metal in the test taken showed the right percentage of phosphorus, is wrong, as although the percentage may be right enough then, yet, as pointed out above, after the recarburisation period it may be entirely different. It seems therefore best to blow in such a way as to obtain a slag as low as possible in iron oxide, to prevent the reduction of iron phosphide during the recarburisation. This can only be done by analysing each slag, and regulating the blow in accordance with the results ascertained in this way. The determination of iron in basic slag by a volumetric method is so rapid that the composition of the slag from one blow may serve as a direct guide in the next. What a fruitful source of danger lies in the reducing action on the slag during the recarburising is evident in that the same addition of 60 kilogrammes (132¼ lbs.) of ferro-manganese to each of two charges may lead in the one instance to a percentage of 0·30 Mn in the finished metal, while in the second the percentage may be half as much again. The richer the slag is in oxides, the greater will be the proportion of the manganese which is slagged away.

The author gives the results of a number of blows, showing the dura-

tion of the blow, and the percentages of iron and of phosphoric anhydride in the slag produced. The following are some of these :—

Percentage of P_2O_5.	Percentage of Iron.	Duration of Blow. Minutes.
19·58	18·69	4·18
20·23	15·96	4·14
21·22	16·63	4·07
22·06	17·95	3·49
23·16	11·19	2·55
24·64	12·40	2·44
25·37	11·33	3·12
24·07	11·59	3·07

These are in each case the average monthly results. In a series of other tables, the results of blows by the ordinary method and that by the one the author describes, are shown side by side, the analyses of the two finished products being shown, together with the percentages of iron contained in the slags. An average of twenty-eight blows by the old method gave finished products (for girders) having the analysis shown below, other twenty-eight by the more modern giving results which are also shown :—

	Composition of Metal.			Iron in Slag.
	Carbon.	Phosphorus.	Manganese.	
Old method	0·11	0·10	0·47	Per Cent. 16·87
Modern method . . .	0·14	0·10	0·55	10·42

	Duration of Blow.	After-Blow.	Spiegeleisen Added.	Ferro-Manganese Added.
	Minutes.	Minutes.	Lbs.	Lbs.
Old method	11·46	4·26	353	165
Modern method . . .	9·25	2·47	330	132

The results are given of a large number of other tests in addition to the above. The converter suffers considerably less under the new process, standing 192·1 charges as an average of six months' work as

compared with 150 charges under the older method, the similar figures
for the bottoms being respectively 33·1 and 29·7.

The present management of the Peine Works state * that this process
is not now in use at that works.

The Basic Blow.—A valuable paper by F. E. Thompson † has
recently appeared on the subject of the conversion in the basic converter.
The charge in the heats studied consisted of 24,000 to 26,000 lbs.,
remelted in the cupola, and charged after the lime was added. The
metal contained 2·75 to 3·25 of carbon, up to 0·25 of sulphur, up to
0·60 of silicon, and manganese up to 1 per cent. Steel plate scrap up
to 4000 lbs. was added at the end of the blow, and 80 per cent. ferro-
manganese. Data for three types of blows are as follows:—

	Lower Limit.	Average.	Upper Limit.
Per cent. phosphorus in pig iron . .	1·98	2·18	2·69
Per cent. of lime added . . .	11·0	13·5	17·0
Per cent. conversion loss . . .	12·0	10·0	19·3
Number of revolutions in foreblow .	806	855	1197
Number of revolutions in afterblow .	425	436	540
Blast pressure, lbs. . . .	30	28	34
Time of blow, minutes . . .	12	14	18
Casting temperature	hot.	hot.	hot.
Per cent. of phosphorus in steel . .	0·065	0·050	0·030
Plate scrap charged, lbs. . .	800	1000	none.

The foreblow is marked by the same phenomena that occur in the acid
blow—pale flame and sparks during the first combustion of silicon and
manganese, an increasing white flame, and then the drop due to the carbon.
After the drop the manganese lines in the spectrum disappear and the
afterblow begins. In a normal blow brown fumes appear at the edge of
the flame before the afterblow begins, and attain a reddish-brown colour
when it is a third completed. They then increase in density, flashing
more and more across the central yellowish-white flame. There is no
distinct change to mark the end of the blow, which must be judged by
experience, aided by certain indications. In this afterblow the phos-
phorus and some of the sulphur is oxidised. The fundamental principle
is to calculate the amount of air and lime required, and to bring them

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* *Stahl und Eisen*, vol. xvi. p. 124.
† *Iron Age*, vol. lvi. pp. 1260–1262 and 1318–1320.

into the bath. The iron and-lime must then be weighed, and the quantity of air determined by counting the revolutions of the blowing-engine. In actual practice the values for air, lime, spiegeleisen, ferro-manganese, &c., are all worked out in tabular form for different weights of the iron charge. The revolutions are counted by an automatic register near the blower. Preferably double counters are used, one for the fore-blow and the other for the afterblow. It is the author's experience that the lime additions, number of revolutions in the afterblow, and even the amount of recarburiser, must be determined to a large extent by the behaviour of the preceding blow and of the blow in progress, as the iron is often somewhat irregular both in temperature and composition when it is poured into the vessel. Some design of mixer might be of advantage. A number of analyses are given to show the variation.

The only regular additions during the afterblow are lime, scrap, and recarburisers. Scrap is added to cool the bath. Lime is generally all added before the converter is turned up for the blow, but it is some-times added during the afterblow to cool the bath and to thicken the slag. This, however, increases the iron in the slag both as oxide and as shot. The blow lasts twelve to eighteen minutes, or about ten and five minutes respectively for the two periods, during which about 8928 and 4960 cubic feet of air per ton of iron are blown in. At one time it was customary to take a ladle test, but this wastes time and cools the bath, so now the judgment of the blower is relied upon, and apparently with satisfactory results.

The after-blow in basic work is similar to that in acid work, and begins when the iron commences to burn, after the usual impurities are removed. With excess of lime there is more complete elimination of phosphorus and sulphur, but more iron oxide goes into the slag. Without excess of lime, phosphorus returns into the metal, and is accompanied by oxide of iron, whilst the slag is thin and wild. The steel becomes cold-short, and shows a characteristic oxide glitter in the fracture. The relation of the conversion loss and phosphorus reduction in a series of blows was as follows :—

Number of Heats in Series.	Phosphorus in Steel.	Average Conversion Loss.
	Per Cent.	Per Cent.
80	0·02	15·5
120	0·04	14·0
68	0·06	13·8
45	0·08	15·0

The effect of varying percentage additions of lime on the loss is shown as follows :—

Phosphorus in Pig Iron.	Lime Added.	Temperature of Blow.	Phosphorus in Steel.	Conversion Loss.	Consistency of Slag.
Per Cent. 2·05	Per Cent. 11·0	hot	Per Cent. 0·040	Per Cent. 13·0	Sticky
2·84	17·0	hot	0·030	19·4	Very sticky

The temperature problem is the most serious one with which the blower has to deal. In addition to the one variable temperature of the acid process, he has the lime addition and the afterblow to consider, and there are none of the accurate indications of the heat. But accurate reading is not necessary, and scrap additions may be made in units of 500 lbs. Possibly this lack of sensitiveness is due to the large amount of heat stored in the slag, whilst in the acid converter there is only the heat of the metal to be taken into account. In the author's experience, if not more than 10 per cent. of scrap is put into the converter the metal is uniform both in temperature and composition, and many successive blows will follow the same routine. Many blowers rely upon flame indications for the temperature. As the blow becomes hotter the brown fumes crowd down to the converter more, and may even obscure the flame almost entirely. The conversion loss is not then as great as in cold blows, in spite of the escape of iron as smoke, since in cold blows more iron is lost in the slag. Cold blows usually result from excess of lime or scrap, but they may also be due to lack of combustibles in the iron, to cold iron, green or cold converters, or to reduced blast pressure. Hot blows usually occur with iron high in combustibles. Phosphorus towards the end of hot blows does not readily pass into the slag, and scrap must be added. When lime is in excess in very hot blows, low phosphorus steel is produced with high conversion loss. The addition of much scrap in hot blows is another cause of conversion loss, as is shown in the following table :—

Average Weight of Scrap Added.	Number of Heats in Average.	Average Loss by Conversion.
Lbs.		Per Cent.
None	390	12·81
1381	362	14·62
2236	197	14·03
3300	26	15·98
41(	2	18·05
176	8	14·83

Very low conversion loss is due to a combination of fortuitous circumstances. During three months' blowing, out of 1084 heats only 102 were below 11 per cent., and in these there were low lime and hot casting temperatures. Eruption of slag and metal from the converter nose is promoted by cold blowing.

The author then quotes from Wedding to show the progress of the elimination, and states that his own experience shows that from iron containing about 2·50 per cent. of phosphorus, approximately half is removed in a normal foreblow. In hot or long foreblows more is removed, and in short ones less. The phosphorus reaction depends upon the melting of the lime, and when this occurs, phosphorus begins to be oxidised whether carbon is present or not. Sulphur is more fixed than other elements. In a normal blow with iron containing 0·10 per cent., about half is removed in the presence of manganiferous slag, and much more may be removed by over-blowing. If sulphur exceeds 0·10 per cent., from 50 to 90 per cent. may be eliminated.

Rephosphorisation may occur if excess of lime is not provided; the slag then becomes wild and puffy. Manganese frequently reverts into the metal, as in the open-hearth furnace. Analyses at the conclusion of the blow before additions of recarburisers are as follows :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
0·03	trace	0·058	0·035	0·060
0·04	trace	0·028	0·030	0·050
0·04	trace	0·053	0·020	0·120
0·04	trace	0·036	0·025	0·032

Analyses of slags, showing averages for respective runs of different months, are as follows :—

	1.	2.	3.	4.
SiO_2 . .	5·12	6·10	7·28	8·14
FeO . .	16·85	15·42	19·89	19·68
MnO . .	3·82	3·89	4·17	4·00
CaO . .	50·04	48·96	48·46	47·28
P_2O_5 . .	20·30	19·92	16·62	16·81
MgO . .	1·21	1·02	0·68	0·52
Al_2O_3 . .	1·40	2·10	2·40	2·50
S . .	0·34	0·29	0·41	0·41
Moisture .	0·91	2·33	0·11	0·68

With less lime, the phosphorus in the slag is increased and lime diminished; oxide of iron is increased by an overblow and by a cold blow;

manganese depends on that present in the iron ; silica is due to that in
the lime, and to the silicon in the iron ; magnesia is increased by the use
of dolomite as lining or flux.   Tables are then given to show the relation
between the silicon in the iron and in the slag, and also between the phos-
phorus in iron and slag.   Very low oxide of iron almost always occurs in
hot blows, and high oxide, over 15 per cent., in both hot and cold blows.
As the oxide increases in the slag the phosphoric anhydride decreases,
and their sum increases with the amount of the iron oxide in a ratio
given in a table.   A thick slag promotes the reaction between lime and
phosphorus, but retards mechanical admixture.   Very fluid slag retards
dephosphorisation, but promotes desulphurisation.   A thin and wild
slag results from deficiency of lime and an overblow.   A sticky, highly-
basic slag is aimed for, so that it may mix readily and yet be sufficiently
cool.   Most slag made in the United States contained 19 to 21 per cent.
of phosphoric anhydride, but the range is 17 to 22, and the average of
several thousand tons exported was 20·65 per cent.

The author then proceeds to deal at length with the details of the
blow.   The afterblow is prolonged or curtailed according to the length
of the foreblow.   The temperature of the bath is judged for the purpose
of making additions, but on this point sufficient indication of the views
expressed are given above.   The effects of the size of the converter nose
are mentioned : a wide nose makes the blow appear hotter, and a con-
tracted orifice may have the opposite effect.   If the scrap addition fails,
or if there is leakage of blast, an extra twenty or thirty revolutions is
given.   Boiling of the metal on adding the recarburiser is obviated by
smaller additions or by slower pouring, and an extra amount must be
used to replace loss.   With continuously hot blows more blast and, if
required, more lime is added.   The quality of the metal must be judged
at the casting-pit by the blower as a guide for the next blow.   Green
converters must be burned out till the tar is coked to some depth ; a
blow in an insufficiently burnt converter causes great wear.   The weight
of the charge may be increased as the lining wears.

Special additions have been made, but without great success.   Fluor-
spar or hammer scale are sometimes used to prematurely liquefy the
slag, thus promoting chemical action and curtailing the afterblow, but
this usually gives cold heats.   The same substances have been added
late in the afterblow, but these often cause high phosphorus, and do not
affect the sulphur, as was hoped.   Ferro-manganese is sometimes added
as fuel in case of a cold blow, but this is expensive.   The addition of
limestone instead of lime produces cold blows, and it is not economical

to use the converter as a limekiln. The converter at best does not wear well, so the blows should be made as short, as economical of heat, and as regular as possible to save wear and tear; and this is the great secret of successful work.

The Osnabrück Steelworks.—At the Georg-Marien works the ochreous iron ores found in the neighbourhood of Osnabrück are made into briquettes, together with pyrites residues, and furnace dust. Bog iron ores from Hanover and Holland are also smelted. These latter are being replaced by Jurassic clay iron ore from the Wiehen range of hills, where in the neighbourhood of Bergkirchen a bed of ore is mined that is from 4 to over 6 feet in thickness. This rests direct upon the Dogger sandstone.*

The works possess three blast-furnaces, which together produce about 90,000 tons a year of Bessemer and foundry pig iron. They are provided with twelve brick stoves, two new blowing engines, &c. In a coal-mixing plant Westphalian coal is mixed with 15 per cent. of fine coal from Piesberg. The works are provided with 132 horizontal coke ovens and 38 ore briquette ovens, in which monthly about 2500 of the ore briquettes referred to are produced.

The pig iron produced is rich in manganese, and it is converted into steel by both the Bessemer and the open-hearth processes. The Bessemer shop is provided with three cupolas and two converters, and can make about 6000 tons of steel a month. This is rolled by the aid of three trains of rollers into rails, plates, and shapes. In the open-hearth works there are five open-hearth furnaces, each capable of yielding about 1000 tons a month. Tyres are also made in large quantities.

Steel Manufacture in Russia.—Some notes on the manufacture of iron and steel in Russia are given by C. Hyde.† Amongst the private concerns engaged in Government work, there are the Poutiloff, Nevski, and Alexandrovsky Works near St. Petersburg. The first of these is the largest, and employs about 7000 men. They have a Bessemer and an open-hearth department, and besides making iron and steel, they also build locomotives, torpedo boats, bridges, &c., and manufacture projectiles. The raw material is imported mostly from England. The Bessemer department contains two 4-ton converters, and the open-hearth department has twelve 10-ton furnaces placed in a straight line with a

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 601.
† *Proceedings of Engineers' Society of Western Pennsylvania*, vol. xi. pp. 231-250.

long casting pit. The rail-mill has a capacity of about 200 tons daily. The plate-mills can only roll plates up to about 80 inches. Hand-labour is largely employed in place of mechanical appliances. At the Nevski Works there are two open-hearth acid furnaces. The Alexandrovsky Works have seven open-hearth furnaces, of which six are basic lined. The metal is tapped directly into the moulds, which are placed on a revolving table in the casting pit. At the Gougon Works at Moscow there are two 30-ton furnaces. The works in the south of Russia are also shortly mentioned.

The Troy Basic Bessemer Plant.—A plan of the works of the Troy Steel Company at Troy, New York, has recently been published.[*] The ores used are chiefly from Lake Champlain and the Hudson River. There are three blast-furnaces, 80 feet high, with 19-foot boshes, and hot blast is supplied by twelve Whitwell stoves. The converting-house is 300 feet south of the blast-furnaces, and it measures 122 by 88 feet. It contains three 15-ton converters, two 50-ton electric travelling cranes, three iron and two spiegel cupolas. Just outside the cupola house two 150-ton mixers are to be placed. A hundred feet south is the stripper building, with two machines, each capable of dealing with 1000 tons daily. The furnace buildings, 25 feet further south, cover 115 by 50 feet, and will contain two soaking pit furnaces heated by four gas producers. The blooming-mill is adjacent, and occupies an area of 265 by 71 feet. It contains a two-high 35-inch reversing train. A 21-inch billet-mill will also be erected. Two shears to cut 12 by 12 inch blooms and 4 by 21 inch slabs, together with a 20-ton overhead travelling electric crane, are provided. The boiler-house, 130 by 80 feet, with twenty 250 horse-power boilers, and also an engine-room, 142 by 50 feet, and a machine shop, are placed on a line to the west. The capacity of the works will be about 700 tons of basic steel daily.

The Cambria Works at Johnstown.—Many improvements have lately been made at the Cambria Works at Johnstown. Otto Hoffman ovens are now built for the recovery of by-products. There are now four 12-ton converters, which are fed from a 300-ton mixer supplied direct from the furnaces. Ladle trucks are used, and are raised by a hydraulic lift 45 feet to the mixer. The standard size of ingot is 19¾ by 22¾ inches, and weighs 6500 lbs. The blooming-mill contains one 48-inch and one 40-inch train and a billet-mill. It is equipped with

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[*] *Iron Age*, vol. lvii. pp. 183–184.

seven pit furnaces. The rail-mill has been remodelled, and consists of a 28-inch three-high train, the first and second roughing stands being driven by an engine of 3000 horse-power. For T-rails the first stand has seven and the second three passes. The finishing train, 125 feet distant, has two passes. The rails are handled automatically, and the hot-bed has been raised to increase the air circulation. The second rail-mill for light rails and girders has a 21-inch rail train, and the tables are here electrically worked. In the roll-mill electric driving is used.[*]

The Agricultural Value of Basic Slag.—Dr. Maercher [†] gives details of a number of experiments made to test the question whether the actual agricultural value of a basic slag was accurately shown by the quantity of phosphoric acid soluble in citrate solution. This was found to be the case.

O. Foerster [‡] observes that it may be deduced from the investigations of Gerlach and Passon that a solution of citric acid of exactly the same acid contents as the ammonium citrate solution employed by P. Wagner will under similar conditions dissolve out exactly the same quantity of phosphoric acid. Three slags gave exceptional results. From these the citric acid solution dissolved considerably larger quantities of phosphoric acid than did the Wagner ammonium citrate solution. The excess of phosphoric acid taken up into solution by the citric acid solution was not precipitated by ammonium citrate. The reason for the irregular action of these slags is no doubt due to the fact that, as a general rule, a solution of citric acid is a much better solvent for all phosphates than is a solution of ammonium citrate of an equal degree of acidity. The variation in the solvent power is not noticeable as long as the solvent is in excess, but it becomes marked directly the substance to be dissolved is in excess, whether this substance is an easily soluble one, such as di- or tetracalcium phosphate, or one that is hard to dissolve, such as the ignited triphosphate; or others that are still harder to dissolve, such as the phosphates of iron and of aluminium. It is evident, the author observes, that those slags which gave irregular results contained a phosphate of calcium or also of magnesium; either it may be a tricalcium phosphate or the compound $(Ca_3P_2O_8)$ 3CaO, which resembles apatite, or some other such compound which yields up a much larger percentage of its phosphoric acid to a citric acid solution than to an ammonium

[*] *Iron Age*, vol. lvi. p. 1090.
[†] *Stahl und Eisen*, vol. xv. p. 957.
[‡] *Chemiker Zeitung*, vol. xx. p. 131.

citrate solution of an equal degree of acidity. The great majority of
slags probably contain more of these phosphates, but, on the other hand,
contain that portion of the phosphoric acid which is insoluble in citrate
solution in the form of iron or aluminium phosphate, which on the one
hand are much less soluble, especially for the duration of attack employed
in the case of slags, and on the other do not show so marked a difference
in their behaviour towards the two solvents. Until it is shown that the
phosphoric acid dissolved by the citric solution is equivalent to that dis-
solved by the citrate, the addition of at least a small quantity of ammonia
to the solution must be continued.

The Origin of the Bessemer Process.—In the course of a presi-
dential address to the American Institute of Mining Engineers in
February 1896, J. D. Weeks [*] gave a Mr. Kelly the credit of anticipating
the inventions of Sir Henry Bessemer. Several long communications
from Sir Henry Bessemer [†] have been published with the object of
refuting these statements. H. M. Howe [‡] has also published a communi-
cation to the same effect, and articles have appeared in the British [§]
and foreign [||] technical journals upholding Sir Henry Bessemer's views.
After pointing out that the contest has no practical value or significance
whatever, the *Engineer* [¶] summarises the matter thus: "The Bessemer
process is not a theory, it is an art. It is not one invention, but fifty.
Kelly's cupola did not anticipate the Bessemer converter as fully as
Newcomen's engine did the modern triple-expansion engine. For New-
comen's engine could work ; it had an economical value ; it revolutionised
the practice of mining."

[*] *Transactions of the American Institute of Mining Engineers* (advance proof). See
also rejoinder in the *Engineer*, vol. lxxxi. p. 538.
[†] *Industries and Iron*, vol. xx. p. 184, 372 ; *Engineer*, vol. lxxxi. p. 299 ; *Engineer-
ing*, vol. lxi. p. 367 ; *Iron and Coal Trades Review*, vol. lii. p. 417 ; *Iron and Steel
Trades Journal*, vol. lviii. p. 373.
[‡] *Engineering and Mining Journal*, vol. lxi. p. 227.
[§] *Engineer*, vol. lxxxi. p. 545 ; *Engineering*, vol. lxi. p. 413 ; *Iron and Coal Trades
Review*, vol. lii. p. 425 ; *Industries and Iron*, vol. xx. p. 191 ; *Iron and Steel Trades
Journal*, vol. lviii. p. 368.
[||] *Stahl und Eisen*, vol. xvi. pp. 341–347 ; *Glückauf*, vol. xxxii. p. 293.
[¶] Vol. lxxxi. p. 545.

FURTHER TREATMENT OF IRON AND STEEL.

The Gjers Soaking Pits.—R. M. Daelen [*] observes that the well-known Gjers soaking pits give the best results when the output is as large as possible. If it is much less than 300 tons in the twenty-four hours, the intervals between the heats are so long, that the pits remaining unoccupied lose too much heat to enable them to subsequently yield ingots of the temperature customary in ordinary work. In cases such as this, it has been customary to heat the pits by some method of firing. To properly carry out this system a group of pits has to be arranged systematically with gas firing, each one being readily and easily separated. This is both difficult to arrange, and inconvenient in actual work. If heating is employed, then not only is there an increased consumption of fuel, but what is much more important, an increased loss of metal by scaling. The loss by oxidation during transport and rolling is about ¼ per cent. Subtracting this, the loss of metal by treatment in a re-heating furnace amounts to about 2 to 2·5 per cent., in heated soaking pits 1 to 1·25, and in unheated ones 0·5 per cent.

The various difficulties which have to be met have led the author to experiment with an arrangement which, although described in Gjers' original specification, has never been really properly tried. This consists of a sort of a movable soaking pit on wheels. The ingot is placed on a firebrick base, which, in the author's experiments, was not on wheels, but fixed. Over this is then placed a firebrick-lined hood. This hood or cover is rapidly heated; the equalisation of the temperature of the ingot is more regular than is usual, the oxidation much less, no scale falling off, and no slag being consequently produced on the bottom of the soaking "pit"; and, further, the equalisation of temperature proceeds

[*] *Stahl und Eisen*, vol. xvi. pp. 61–63; *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 73–75.

more rapidly.   These effects are all due to the atmosphere around the
ingot being as quiet as is possible owing to the enclosing hood.   In the
ordinary badly-closed up pits there is a constant introduction of fresh air
into them, causing loss of heat and increased oxidation.   With regard
to the question of oxidation, there can be no doubt that the ingot
when under the hood is constantly surrounded by a reducing atmos-
phere.   The experiments were carried out at the Rhenish Steelworks
at Ruhrort.

Reheating Furnaces.—J. S. Smeysters * describes a reheating
furnace of the Bidermann and Harvey type installed at the Couillet
Steelworks.   It is supplied by six gas producers.   The hearth, provided
with four working doors, is 8·5 metres long and 2·5 metres wide.   It is
used for reheating large steel ingots, of which 100 to 120 tons are dealt
with in twelve hours.   The consumption of fuel amounts to 3·4 to 3·6
tons per twelve hours.   The installation of a furnace such as the two at
Couillet costs about 30,000 francs.

Illustrations are published † of the Morgan-Allen heating furnace for
continuous work.   It is provided with an inclined bed sloping down to
the fire end.   Cold ingots are charged at the top end by a mechanical
device, which automatically opens and closes the door, and as they are
inserted they push the ingots already in the furnace farther down.   Gas
firing is used, and the furnace works exceedingly economically, as the
cold ingots absorb the heat readily.

Welding Chrome Steel.—Referring to a statement by Lieutenant-
Colonel Levitzky ‡ regarding the difficulty of welding chrome steel,
R. Brown § notes that during a long experience in the working of chrome
steel he has had no difficulty in welding as long as the work was pro-
perly and carefully carried out.   The whole secret lies in getting the
smith to tap the pieces very gently with his hammer at first, and gra-
dually increasing the strength of his blows as he proceeds.   In the event
of the pieces being large, they may eventually be put under the steam-
hammer with perfect safety.   The same principle applies when working
out the ingot.   If the strokes are not very light at first, the tendency
will be for the steel to fly off into small pieces.

* *Annales des Mines de Belgique,* vol. i. pp. 100–102.
† *Iron Age,* vol. lvii. p. 527.
‡ *Journal of the Iron and Steel Institute,* 1895, No. I., p. 427.
§ Communication to the Secretary, February 3, 1896.

Electric Welding.—P. Hoho [*] has described the system of electric heating and welding devised by himself and Lagrange. As previously mentioned in these abstracts,[†] it consists in passing the electric current through the work, which is immersed in a bath of conducting liquid. When low potential is used, simple electrolysis results ; but with high voltage, the desired heating takes place. In practice, the temperature of the bath should not exceed 60° to 70° C. The bath is a metal-lined receptacle connected to the positive pole, and the work is connected to the negative terminal. From 125 to 200 volts are used, and 35 to 40 kilowatts applied for 30 to 50 seconds will raise the ends of a 1½-inch bar of iron to welding temperature. When a portion only of a large article is to be heated, it is only necessary to cover the remainder with insulating material, and then to expose it in the electrolyte. The action and consequent heating then takes place solely on the uncovered parts. The uses to which this method is applicable are heating for welding, stamping, forging, tempering and hardening, and other purposes. Of these some details are given as regards welding, forging, continuous annealing of wire, manufacture of chains, drop forging, and tempering and hardening various articles.

Recent experiments made with the Thomson and with the Lagrange-Hoho electric welding processes at Cologne are described by Fuchs.[‡] Six tests of different kinds of steel required with the Thomson method the utilisation per square centimetre of from 2·81 to 4·87 electric horse-power, and three with the Lagrange-Hoho process required from 9·3 to 15·4 horse-power per square centimetre welded. Despite the much larger power required, the latter process is nevertheless of value for many purposes.

A detailed description has been published[§] of the Zerener electric casting and welding process. Illustrations are given of various welding appliances, in which an electric arc is deflected by a horse-shoe magnet so as to form a suitable flame.

The Zerener or deflected arc system of electric welding is also described by T. Scott Anderson.[||]

In welding pipes at a works at New Haven, Connecticut, for making flat coils 10 feet long by 8 inches wide an electric welder is used, and no care is taken to make the joints come in the flat parts of the coils, as

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[*] *Electrical World*, through the *Iron Age*, vol. lvi. pp. 1268-1269.
[†] *Journal of the Iron and Steel Institute*, 1893, No. II., p. 478.
[‡] *Berg- und Hüttenmännische Zeitung*, vol. liv. p. 420.
[§] *Electrotechnische Zeitschrift*, vol. xvii. p. 46, with six illustrations.
[||] *Engineering*, vol. xlx. p. 664.

the welds can be bent equally well with the other parts. In preparing the ends to be welded, one end is cut square and the other is bevelled off on the inside. The exterior is thus first heated, and the weld finished towards the centre, so that the internal diameter is preserved.[*]

Some experiments have been made at Deptford on electric welding with the ordinary lighting current. Current at 5000 volts supplied by the Ferranti dynamos was let down to 300 volts in a transformer, and further reduced in the welder, which contained about 300 turns of primary to the one of the secondary coil. This coil has clamps attached in which the work is held, and with its aid a large number of tyres have been welded successfully.[†]

With the aid of seven illustrations, R. M'Culloch [‡] describes in detail the process of electrically welding tramway rails adopted by the Johnson Company, and compares it with the cast-welding process worked by the Falk Company of Milwaukee. The latter consists of clasping the ends of the rails for about 8 inches on each side of the joint by means of a mould, and then pouring the mould full of molten iron. The iron solidifies on the rails round the joints, and makes a partial union with it. The apparatus consists of a cupola 2 feet in diameter, mounted on a heavy truck. The cost of either process is not greater than that of the old fish-plate method.

Welded Steel Mains.—J. G. Stewart [§] discusses welded steel mains and joints. He considered that weldless tubes are less trustworthy than welded tubes, the quality of the latter having been so much improved.

Wire Rod Rolling.—W. Garrett [‖] discusses the development of American wire rod rolling. In 1868 a plant was put up in Newbury, Ohio, for rolling puddled iron into wire rod, but it was a failure, as the iron was too red short. About the same time the Cleveland Rolling Mill Company turned its attention to utilising the crop ends of Bessemer steel rails for this purpose, and finally succeeded in doing so without slitting the crop ends into three parts. From 1871 to 1881 the billets thus rolled were the chief source of wire rod, the amount in the latter

[*] *Iron Age*, vol. lvii. pp. 859–860, with illustrations.
[†] *Engineer*, vol. lxxxi. pp. 607–610.
[‡] *Journal of the Association of Engineering Societies*, 1895, p. 175.
[§] Paper read before the Manchester Association of Engineers, *Engineer*, vol. lxxxi. pp. 226–227.
[‖] *Iron Age*, vol. lvii. pp. 15–20, with illustrations.

year being 17,459 tons, of which half was for spring wire. A method of using up the crop ends of the billets themselves was also devised, use being made of box piling, and soon after it was found possible to melt up steel scrap in a cupola. In 1871 the above-named company put down the Brick mill, and produced 14 tons per day in the double turn. This consisted of a single train with five stands of rolls, on which 15 to 25 lb. billets were rolled. In 1875 the Belgian system came forward. This consists in doubling back into the rolls the end of the rod as soon as enough has emerged from the previous pass. About this time also two rods were rolled at the same time, but only in the finishing rolls, and no further development in this direction took place for ten years. In 1880 the Cleveland Company rolled 36 tons per double turn. In 1876 the author sketched out his plan of mills, and J. Hemphill devised the gearing for driving it, but it was not until 1882 that the plan was adopted. In the previous year the duty on imported wire rods was increased, and this caused nearly all the mills to shut down; but H. Chisholm, of the Cleveland Company, determined to make the rods by the new method, and in three months' time the production was 72 tons in the twenty-four hours. It was soon found that the finishing passes could be overcrowded, so a double repeater was put in, and double passes used. It was, however, very dangerous to deal with these double loops, but this was obviated by the use of an inclined floor, first put down by H. Roberts, of Pittsburgh. No hook-boys were then required, and the use of automatic reels enabled the largest output to be handled. The increase in the output for various years in tons per twenty-four hours has been as follows :—

Year .	. 1870	1875	1880	1885	1890	1895
Tons .	. 14	18	28	100	200	280

No less than fourteen Garret mills have been put up since their inception thirteen years ago, and it may be assumed that their capacity is over a million tons, and other mills will bring the total possible output to 1,400,000 tons yearly. The author also comments upon the continuous mill, but naturally dwells mostly upon his own type, and then he shows how the production of 4-inch soft steel billets sells next in volume to pig iron.

C. W. Bildt* observes that iron and steel wire rods, if excellent in character, must not only be of metal of a perfectly uniform composition, but that metal must also have been treated mechanically under identical

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* *Jernkontorets Annaler*, vol. 1. pp. 150–162.

conditions. Rods which have been rolled at a brown or a blue heat become brittle, and will not stand any further treatment without a preliminary annealing. They must therefore be rolled at a temperature which is adequately high, and this is accompanied by considerable oxidation when the wire is subsequently cooled down slowly in the air, making it irregular in character. To prevent this oxidation, the author recommends the use of a water-bath, through which the rolled wire is passed direct after leaving the rolls. This method is employed at several works in the United States. This cooling induces a greater degree of toughness in the metal. The wire must not, however, become entirely cooled, or it would otherwise, of course, be hardened. It must only be cooled down to a definite temperature—usually to a dull red or a brown heat. This temperature is dependent on the percentage of carbon in the steel. This cooling not only toughens the metal, but prevents the formation of a great deal of scale, and the scale which has already formed is thrown off by the contraction of the metal, and the wire when it leaves the bath is fairly free from scale, so that it has a clean and even surface. If it has to be subsequently zinced, tinned, or electro-coppered, the metal adheres readily. The arrangement of the plant is shown by illustrations, and curves are given showing the increase in the tensile strength of the metal produced by cooling down to different temperatures in the bath. Down to a certain temperature this cooling increases the tensile strength and limit of elasticity without prejudicially affecting the elastic limit. The tables refer to two wires cooled in different ways, and having the following chemical compositions :—

Carbon.	Manganese.	Silicon.	Sulphur.	Phosphorus.
0·032	0·042	0·011	0·004	0·093
0·810	0·590	0·107	0·004	0·047

The author points out that a metal high in phosphorus when treated in this way becomes more ductile. Wires containing from 0·4 to 0·5 per cent. of carbon only require about half the acid for cleaning, if they have been treated in this manner, of that which is necessary if the metal has been allowed to cool down in the ordinary way in air. With higher carbon a larger quantity, proportionately, of acid is required, while if the percentage of carbon is lower, the quantity of acid needed is less. Not only, therefore, does this water-cooling process lessen the exposure of the wire to the injurious action of acid, but there is a considerable saving in the quantity of acid used. The arrangement of the plant and its method of manipulation are described.

The Klatte System of Rolling Chains.—O. Klatte * describes, with the aid of nineteen illustrations, his method of manufacturing chains by rolling. A bar of special shape is employed, which is rolled down to size, submitted to a punching process, pressed into the form of a rough chain, and then completed by further operations, the various stages being well shown by the illustrations accompanying the paper. These include the machinery employed.

Manufacture of Tubes.—A report by the United States Consul-General at Frankfort on the Erhardt process for manufacturing tubular bodies has recently appeared.† This process appears to be a modification of the method of drawing by means of a die and mandrel; and one of its features is that some space is left between the work and the die or the mandrel in order to allow the metal to flow. In some instances this is done by making the die or mandrel polygonal. The material is worked hot, and is shaped into shrapnel shell bodies, compressed gas bottles, and similar articles.

In discussing the best material for iron locomotive-boiler tubes the American Railway Master Mechanics' Association expressed the opinion that steel tubes pit more readily than iron, and that, with bad water, there is more difficulty in keeping them tight. They recommend that tubes and tube ends should be made of charcoal pig iron which has undergone a second refining process of being boiled with charcoal.‡

An Enormous Plate.—At the Cardiff Exhibition is a boiler plate some 70 feet long. Particulars have been received§ from the Stockton Malleable Iron Company of a still larger plate. The total length sheared is 76 feet 3 inches. Its rolled width varied from 5 feet 2 inches to 6 feet 2 inches. The sheared width is 5 feet, and the thickness 0·6 inch. The sheared weight of the plate is 5 tons 10 cwt.

Plate-Bending Rolls.—Illustrations have appeared ‖ of some large vertical plate-bending rolls adopted for bending boiler plates 1⅜ inch thick, over 6½ feet wide and 25 feet long. The vertical design has been adopted in place of horizontal rolls, to avoid the distortion due to the weight of the plates. The tool has two driven rolls 16 inches in

* *Stahl und Eisen*, vol. xvi. pp. 152–158.
† *Engineering and Mining Journal*, vol. lx. pp. 463–464.
‡ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. p. 521.
§ *Engineer*, vol. lxxxi. p. 506.
‖ *Iron Age*, vol. lvii. pp. 409–410.

diameter, and one idle roll 20 inches in diameter. The top housing of the outside and idle roll can be lifted, and the roll is then swung downwards to liberate or insert the plate. The rolls are driven by an engine having two 8 by 9 inch cylinders.

Drawings have been published * of a machine for bending hot sheets at Romilly-sur-Seine. It consists of a hydraulic press built in the style of a steam-hammer.

Steel Rails.—The first steel rails, according to R. W. Hunt,† in the United States were imported and laid by the Pennsylvania Railroad Company, the first Bessemer steel made in the country was manufactured at Wyandotte, Michigan, and the first rails made from it were rolled at the North Chicago Mill on 24th May 1865, whilst the first commercial order for steel rails was filled at Johnstown in 1867. The production in that year was 2550 tons, rising to 34,000 in 1870, and 1,438,155 tons in 1882, when the out-turn of Great Britain was exceeded. The largest production was 2,354,132 tons in 1887. To cope with the out-turn in the earlier days when all the pig iron had to be melted in cupolas, it was determined at the Cambria Works by G. Fritz, A. L. Holley, and the author to make the cupolas run continuously. For this purpose a forebay was to be attached to the cupola similar to that that was used with blast-furnaces. Owing to pressure of time the arrangements were not completed, but a hole had been cut in one of the cupolas, and stopped temporarily when it was started. During the night the furnace-man knocked in this hole after adding more lime to the charge. When they inspected it the next morning the slag was coming away successfully, somewhat to their chagrin at not having seen that the forebay was unnecessary. A summary of the cost of steel rails in 1874 and 1875 is given, and reference is made to the M'Kenna process of re-rolling worn rails. ‡

J. Whitestone § advocates the superiority of the bullhead rail, and urges the advantages of steel over wooden sleepers.

Steel Sleepers.—J. Schuler ‖ reviews the various forms of steel sleepers that have been introduced during the past year, and expresses

* *Portefeuille économique des machines*, 1895, p. 178–181.
† *Iron Age*, vol. lvii. pp. 34–35.
‡ *Journal of the Iron and Steel Institute*, 1895, No. II., p. 530.
§ *Engineer*, vol. lxxxi. p. 137.
‖ *Organ für die Fortschritte des Eisenbahnwesens*, 1895, pp. 178 and 199.

the opinion that the employment of metal sleepers would be materially extended if they were supplied with elastic seatings.

J. A. Griffiths * describes the use of steel sleepers on the Normanton-Croydon Railway, North Queensland.

The use of steel sleepers in India is fully discussed in the *Bulletin of the International Railway Congress.†*

Metal Underframes for Railway Waggons.—J. Morandière ‡ gives a full description of the details of construction of the iron underframes for railway waggons recently adopted by the West of France Railway Company. In the underframes used the number of pieces of forged iron is reduced to a minimum, and the labour in construction is lessened by the use of bar iron of workable dimensions.

A Large Stern Frame.—Illustrations have been published § of a very large wrought iron stern frame built at Paterson, New Jersey. The external dimensions are 21 feet 2 inches by 28 feet 10 inches, and the inside dimensions of the rectangular part is $8\frac{1}{4}$ by 22 feet. The metal is 18 inches thick in the hub, and the total weight is 26,000 lbs. Owing to its large size it partly lapped over the second track on the railway. It was mounted on a pivoted platform on a truck for transport.

Structural Steel.—J. Christie || deals generally with the subject of structural steel, reviewing briefly its manufacture by the Bessemer and open-hearth processes, both acid and basic. Attention is also paid to the composition of the metal, and to the various chemical and physical tests that are applied, and to the effect of working on its properties.

A committee appointed by the Association of American Steel Manufacturers has proposed ¶ some standard shapes for rolling beam and channel iron. The channel sections proposed vary from 3 to 15 inches in depth, and the beams from 3 to 24 inches. Of the larger sizes the weights are to vary by uniform increments of 5 lbs., medium sizes by $2\frac{1}{2}$ lbs., and smaller sizes by 1 lb. In the 24-inch beam, for instance, the minimum weight is 80 lbs. and the maximum weight 100 lbs. The minimum sizes

for flanges, webs, and areas are also specified, and a suggestion is also made with regard to equal and unequal angle iron.

· F. W. Lührmann * refers to the use of steel for building construction purposes in the United States. The enormous weight of some of the excessively high buildings erected has led to the use of iron for structural support instead of brickwork. He describes the mode of use of the metal, giving a description of the system adopted in the erection of Fahy House, Chicago. The Manhattan Life Building, New York, has a net weight, without foundation, of 30,000 tons, or 32,500 gross. This weight is borne by twenty-nine steel columns, resting on fifteen of masonry. The weight borne by the several columns is not identical, some supporting as much as 2000 tons. The metal used is soft steel of 25 tons per square inch, with an elongation of 25 per cent. Cast iron is nearly entirely excluded in building construction in the United States.

E. Schrödter, in a paper † read before the Technical Association at Frankfort-on-the-Main, considers the uses which are now made of iron in building construction. He refers to the question historically. He observes that iron as now used in buildings may be divided into cast iron and malleable iron, and he refers to the uses to which each kind is put. Malleable iron must be subdivided into weld iron and ingot iron. The former is of little account, while ingot metal, on the other hand, is used in all kinds of ways. The question of the manufacture of the ingot metal is considered, and the physical requirements of the metal as made are passed in review. The author strongly favours the use of the metal in building construction, and he thinks that nowadays one may speak not merely of iron construction, but even of iron architecture.

A report has been published ‡ by a technical commission appointed to investigate the fire-resisting powers of iron pillars used in warehouse construction. The general conclusions show that malleable iron pillars have very small fire-resisting properties, their stability being entirely destroyed at a temperature of 600° C.

L. Eidlitz § discusses from a mathematical point of view the strength of pillars, and gives a number of tables showing the breaking weights for various forms of cast and wrought iron pillars loaded in different ways.

* *Stahl und Eisen*, vol. xv. pp. 1046-1048, four illustrations.

† *Ibid.*, vol. xvi. pp. 291-294.

‡ *Vergleichende Versuche über die Feuersicherheit von Speicherstützen*, 4to, 84 pp. with seventeen plates. Hamburg : Otto Meissner. 1895.

§ *Proceedings of the American Society of Civil Engineers*, vol. xxii. pp. 119-158.

Ornamental Ironwork.—D. A. Walter[*] describes and illustrates some Irish ornamental ironwork of the eighteenth century as exhibited in the streets of Dublin, and remarks on the excellent work produced in iron in an age so remarkable for its lack of artistic feeling. The examples include scroll-work, arches, and gateways, and a number of lamp standards of considerable beauty.

Some illustrations are given[†] of early and later forms of plain and ornamental andirons, together with a short description of their manufacture. The latter forms are highly ornate, being decorated with baskets, curls, and twists. It is stated that each workman devotes all his time to making single parts, which are then welded together, and in this way great perfection is attained with considerable rapidity. One illustration of an andiron is in the form of a dragon, which employed three men for three weeks.

The Manufacture of Anvils.—Previous to 1891 all wrought iron anvils were imported into America; but in 1895, out of a consumption of 800 tons, 500 tons were produced in that country. Formerly the anvils were built up of four corner pieces, and the heel and horn pieces welded to a central core. A process is now in use of piling material to make two blooms to form the entire upper half and the entire lower half, which are then welded together in the centre. The steel face is then welded on and tempered. Heavy steam-hammers and dies are used.[‡]

Japanese Swords.—B. S. Lyman[§] gives a series of notes on metallurgical and other features of Japanese swords. The metal used in making them has usually been of native manufacture. Sometimes steel is used alone, sometimes wrought iron is introduced into the pile, which is welded, drawn down, doubled, cut up, and repiled very many times with infinite care. There may be as many as four million layers in the sword due to all this working. When iron is used, care is taken to keep the steel at the part which is to form the cutting edge. After the blade is shaped under the hammer it is dressed with a kind of drawknife and the file, and is then tempered. To do this, it is coated with loam so as only to leave the edge exposed, and after heating it is quenched so as to give the proper temper to the edge, only leaving the back of tough metal. The grinding and polishing are trades distinct from the smiths,

[*] *The Antiquary*, vol. xxxii. pp. 22, 81, 149.
[†] *Iron Age*, vol. lvi. pp. 744–745.
[‡] *Iron Trade Review*, vol. xxix. No. 13, p. 5.
[§] *Journal of the Franklin Institute*, vol. cxli. pp. 13–26, with illustrations.

and in these operations the same loving attention is given. In addition the author gives much interesting matter in relation to the makers, shapes, and nomenclature of swords.

Steel Wool.—A product called "steel wool" is now manufactured as an abrading material, and is intended for use instead of sandpaper, emery-paper, and similar substances. It consists of fine shavings of steel made by a special machine, and it is stated to possess many advantages. Ordinary steel shavings have been employed for some time for abrading and polishing purposes; but it is difficult to get them of uniform grade and temper, so the steel wool has been introduced.[*]

The Manufacture of Tin Plates.—An illustrated series of articles have recently appeared [†] dealing comprehensively with the manufacture of tin-plate in the United States, where it is stated that not less than 250 manufacturers are interested. A plan of a six-mill tin plant of American design is first given, and then the engine design for hot mills is discussed. For the sake of comparison an English plant is illustrated, and the differences are pointed out. In the American practice direct motion or intermediate gearing is used independently for each mill, and the doubling and trimming shears are seldom operated from the mill train. The foundations and general designs are heavier, but the cost was not excessive, owing to the period of depression that occurred when most of the plants were built. The packs are rolled to greater length, so the housings are made heavier. The hot rolling and the pickling operations are then described and illustrated, with plans of the furnaces and other apparatus. The annealing and cold-rolling departments are similarly dealt with. Attention is then turned to the tinning department, and some illustrations are given of tinning and cleaning machines that are in use.

A plan, photographs, and description of the Laughlin tin-plate works at Martin's Ferry, Ohio, have recently been published.[‡] The mill is supplied with slabs from a rail-plate train in another works of the same company. These slabs are $2\frac{1}{4}$ by 15 by 26 inches, and after heating they are given four passes in the roughing rolls, one in the bull-head, and two in the finishing rolls. The sheets are taken automatically to the shears, which cuts and also piles them. The hot-rolling department contains

* *Iron Age*, vol. lvii. p. 871.
† *Ibid.*, vol. lvi. pp. 1048, 1092, 1152, 1219, and 1266.
‡ *Ibid.*, vol. lvii. pp. 363–364.

four hot mills, 24 by 32 inch rolls, four heating and four bar furnaces. A 1000 horse-power engine drives the mill. The plates are treated in a Gray pickling machine, and taken to three annealing furnaces. There are five cold mills, 22 by 34 inches in size, and these are driven by a 28 by 48 inch engine. The cold mills are placed in two parallel lines. The tinning-house has eight tinning sets. The output is 600 boxes daily of bright and terne plates.

Galvanising.—W. T. Flanders * gives some notes on galvanising. The kettle should be large enough for continuous work, and should not be less than 2 feet deep, 1½ foot wide, and 3 feet long. A firing space or flue, 6 inches wide, should be left round it, and the bottom should be supported on a brick pillar. An oven is used for drying the work, or a hot plate may be used for small articles. Wrought iron or steel is cleaned or pickled in dilute sulphuric acid of one to ten, but stronger acid may be used for sheet iron. Sandy castings are best cleaned by keeping them wet with the pickle. Work cleaned by tumbling or scaling may be cleaned by dilute hydrochloric acid, one to three. Articles that have been pickled too long should be dipped in boiling lye, allowed to rust for twenty-four hours after rinsing, and then again treated in dilute hydrochloric acid. Before galvanising the work is dipped for a few minutes in a mixture of water, hydrochloric acid, and sal ammoniac, and then dried. Flux of sal ammoniac is used on the zinc bath, and the kettle is kept as full of articles as possible to ensure regular withdrawals. Cast iron remains in the bath three to thirty minutes, but wrought iron can be removed as soon as it attains the same temperature. After the metal commences to take the coating it should be thoroughly washed in the flux. Articles can be dipped singly, wired together, or in baskets. After the coating is complete, the bath is skimmed and the work carefully withdrawn, being tapped to remove surplus zinc, and dipped into cold water to set the zinc. Spangled surface is produced by air-cooling before quenching. Success depends largely on the temperature and regularity of the bath. For grey and malleable iron it should be about 30 degrees above the melting-point of zinc, but for basket work it may be rather hotter. Dross should be removed from the bottom of the bath by a perforated ladle at intervals and before cooling.

Electro-Metallurgy.—A comprehensive and authoritative text-book on the extraction of metals by the aid of electricity has been published

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* *Iron Age*, vol. lvii. pp. 518–520.

by W. Borchers.* A condensed description of the chief properties and
chemical methods of preparation of each metal precedes the discussion
of processes for its separation by electrolysis. Iron comes within the
field of electro-metallurgy chiefly in respect of the magnetic dressing of
its ores, and of the working of iron and steel by various welding pro-
cesses. Electrolytic refining has been proposed, but remains to be
achieved. There is only a trifling demand for pure chromium and man-
ganese, their respective iron alloys sufficing for the chief purposes to
which these metals are put ; but in the event of need arising, there should
be little difficulty in meeting it. Both chromium and manganese can be
reduced from their aqueous solutions when a high-current density is
used. The electrolytic refining of ferrochromium and of ferromanganese
has been tried, but without much success.

The Turner Waste Pickle Recovery Process.—In discussing
the treatment of trade waste, W. Naylor † refers to the Turner recovery
process for the treatment of waste pickle in galvanising works. This
process has been in successful use for four years at Walsall for spent
hydrochloric acid. The liquid is run into a dish-shaped receptacle over
a coke fire, and concentrated. The ferric chloride is removed and
placed between the fire and the dish, where it is decomposed into
chlorine and ferric oxide. The chlorine passing over the bridge comes
into contact with steam from the waste and forms hydrochloric acid,
which is condensed in a tower for re-use. The oxide is used for fettling.
Two furnaces at Messrs. Walker Brothers treat 1000 gallons of waste
daily, yielding 300 to 350 gallons of acid and 1 cwt. of oxide. About
four tons of coke are used weekly.

Utilisation of Scrap Material.—The committee on the utilisation
of scrap, reporting to the last annual meeting of the Master Blacksmiths'
Association, describes the Southern Pacific Railroad's method of working
up old material.‡ In 1880 the accumulation of scrap iron at the
Southern Pacific shops at Sacramento, California, was very important,
as the price of iron was higher than at present, and there was little
market for the scrap. A small rolling-mill, with a single train of 12-inch
rollers, was constructed with the idea of working over the old scrap, and
from the report of the foreman of the blacksmith shop it has proved

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* " Elektrometallurgie." Brunswick, H. Bruhn, 1896. A summary of the contents
of this work is given in the *Electrician*, vol. xxxvi. pp. 659-661.
   † *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 388-405.
   ‡ *Iron Trade Review*, vol. xxviii. No. 46, p. 13.

very useful. Material which has been in use some time, subject to heavy strain and severe shocks, is cut up into short lengths and stacked into 200-lb. piles. It is then placed in a blooming furnace, and after being brought to a proper heat is put under a steam-hammer and forged into billets or slabs. These are again cut up, repiled, and subjected to the same treatment as before. This time they are forged to the proper dimensions for use. Some of the billets are rolled into such shapes as to supply bar iron, fish-plates, spikes, bolts, nuts, &c. The annual output is from 10,000 to 12,000 tons. The cost is about ½d. per lb. All good iron that comes in with the scrap is cut up into such lengths as is required for waggon repairs, &c., but all iron that has been bent to a sharp angle is worked. Old axles are rolled into bars 6 inches by ¾ inch, and cut up into 3-foot 6-inch lengths. These plates are collected in sufficient quantities to make new axles. This method is considered better than flattening the old axles under a hammer, cutting them in the centre, and repiling them. Steel rails are converted into brake-beams by plating out the head of the rail to the same thickness as the web, thus making a T-section. This is then sheared to the shape required.

The Thames Ironworks.—A detailed description has been published of the works of the Thames Ironworks and Shipbuilding Company, Limited.* It is illustrated by views of the principal departments, plans of the works, and drawings of the more important machines.

* *Engineer,* vol. lxxx. pp. 567-577.

PHYSICAL PROPERTIES.

Micro-Metallurgy of Iron and Steel.—J. E. Stead [*] describes the rise and progress of micro-metallurgy of iron and steel, and gives at length the methods for polishing specimens as adopted by Sorby, Martens, Arnold, Osmond, and his own modification of Osmond's method. After dealing shortly with the other apparatus used, the author gives the following list of constituents and the authorities for the use of those names: 1. Ferrite (Howe). 2. Cementite (Howe); carbon of normal carbide (Ledebur); reheated carbon (Osmond and Werth); carbon of cementation (Caron). 3. Pearlite, pearlyte (Howe); perlite (Osmond); pearly constituent (Sorby). 4. Martensite (Osmond). 5. Troostite (Osmond). 6. Graphite. 7. Temper graphite (Hadfield and others); temper carbon (Ledebur). 8. Slag and cinder.

In a subsequent paper [†] the author gives the results of a preliminary examination of malleable castings. The following facts are established:—

1. That in certain ordinary malleable castings, when the section is sufficiently great in diameter, the polished and etched surface presents to the eye a series of what appear to be five clearly defined zones. (a) The outside skin of iron and silica; (b) an area of almost pure ferrite; (c) an area of patches of pearlite and ferrite; (d) an area of almost pure pearlite; (e) a central portion containing meshes of cementite filled in with pearlite and some temper graphite. 2. That on ordinary castings there is sometimes found a skin which consists of iron and free silica, the result of intermolecular oxidation of the silicon in that area. 3. That, coincident with the removal of carbon, the iron crystallises in the columnar form, the crystals radiating perpendicularly from the surface to the interior. 4. That if sufficient time is given, the whole (except perhaps traces) of the carbon, whether in the free or

[*] *Proceedings of the Cleveland Institution of Engineers*, 1895, December, pp. 53–78.
[†] *Ibid.*, pp. 79–101.

combined state, may be oxidised and removed from small sections of both grey and white iron and steel by annealing at a good red heat. 5. That when graphite or temper graphite is removed it first passes into combination with the iron, and is then oxidised and leaves the metal. Osmond's bibliography of the general subject is appended and brought up to date, with forty-nine references.

A. Martens * discusses Osmond's † method for the micrographic analysis of carburised iron. Osmond considers that the best way to prepare sections is by means of a specially prepared emery-paper. This is effected by rewashing in the most careful manner the very finest kind of washed emery. This is then mixed with albumen and transferred by a brush to paper. The section is prepared by repeated treatment with emery-paper thus prepared, and of constantly increasing degrees of fineness, and at right angles to the previous direction. The author's personal experience is in accord with this. In addition to the chemical methods Osmond considers the methods of polishing of great importance in the micrographic analysis of iron. He employs three methods : (1) polishing in bas-relief ; (2) "etch-polishing " ; and (3) etching in the ordinary sense with chemical reagents. With regard to the first of these, the desired result is obtained by placing the metal on a soft surface during the process of polishing. Osmond employs a double thickness of soft cloth, and Martens has found that soft indiarubber also gives satisfactory results. The softer parts of the metal are in this way more rapidly attacked by the polishing agent than are the others. A kind of "relief" results, in which the various components are more or less sharply-defined from each other. The "etch-polishing" method has been prepared by Osmond. It is as follows :—Ten grammes of liquorice root are allowed to stand for four hours in 100 grammes of water. The solution is then filtered and allowed to stand for eight days. It decomposes rapidly and becomes a useful etching agent. Calcium sulphate is mixed with this solution, and used for polishing, employing a parchment foundation. Certain structure-elements are in this way bleached and others not, two groups being distinguishable. In etching, Osmond first eliminates the relief and the coloration that has been effected, by polishing with rouge on an elastic bed, and then etches. He prefers for this ordinary tincture of iodine, using one drop for each square centimetre of surface, allowing the tincture to act until.

* *Stahl und Eisen*, vol. xv. pp. 954-957.
† *Bulletin de la Société d'Encouragement*, vol. x. pp. 480-516.

decolorised, and then washing with alcohol of 95 degrees strength, determining the degree of action by the aid of a microscope, and repeating if necessary. The first attack may be made with tincture diluted to half its original strength. The iodine solution again effects a subdivision into two groups of coloured and uncoloured constituents. By using the three methods one after the other, and disregarding slag, Osmond states that in this way five main constituents or "texture-elements" can be distinguished, the microscopic reactions of which are definitely distinct. In addition, others may be subsequently discovered as the knowledge of the subject becomes more extended.

(1.) The main constituent of carburised iron is the more or less pure iron itself. Osmond, adopting Howe's term, names this ferrite. On beginning relief-polishing ferrite gives a dead polish, which under subsequent treatment becomes granular. In etch-polishing the same action takes place, the ferrite not assuming any coloration, and etching with tincture of iodine yields the same results. Ferrite remains always uncoloured.

(2.) Cementite is the second main constituent according to Osmond. This is especially marked by its hardness, which is equal to No. 6 of the Mohs scale. This high degree of hardness—greater than that of any other structural constituent of carburised iron—admits of its ready identification on relief-polishing, provided it is not embedded in too fine a condition in a soft material. Cementite represents the carbide to which the formula Fe_3C has been given. Osmond considers that the cementite of cemented iron is identical with the hard constituent of cast and hammered steel. On etch-polishing it assumes no colour, and iodine tincture is also without such action. Under vertical light cementite is silvery white in colour.

(3.) The third constituent is named by Osmond sorbite, after Sorby, who first described the "pearly constituent" of iron (perlite of Howe). This he thinks is not a mere mixture of the two constituents above described; for on etch-polishing a coloration results, and iodine tincture also produces this. Perlite consists of layers, at one time of cementite and this third main constituent sorbite, or at others of sorbite and ferrite, of two kinds of sorbite showing different coloration, and finally occasionally of cementite and ferrite, perhaps with or without an intervening layer of sorbite. As to the chemical constitution of sorbite Osmond can as yet make no statement. It certainly contains carbon, and Osmond thinks this is hardening carbon.

(4.) A fourth main constituent which always forms on hardening is

called by Osmond martensite. If, for instance, iron with 0·45 per cent. of carbon is heated to 825° C., and then plunged into a freezing mixture of a temperature of – 20° C. from 720° C., relief-polishing yields but little result, but etch-polishing shows the texture. Groups of needles or of parallel threads become evident. Three groups of threads, parallel to the three sides of a triangle, are often seen together, crystallites of the cubic system. Martensite is not always coloured on etch-polishing, and even then only shows a yellow tinge. By using tincture of iodine, however, it becomes yellow, brown, or black, according to its percentage of carbon. Owing to the irregularity of the colouring it is uncertain whether or no to consider martensite as an elemental constituent; but it retains its form even in the hardened portions, as well in the softest as in the hardest iron, with the single difference that the needles vary in length according to whether the iron is more or less carburised. The forms are characteristic, and admit of variations in the degree of hardness being distinguished. Martensite is not with certainty a definite compound between iron and carbon. It represents the crystalline organisation of an allotropic modification of iron under the influence of carbon.

(5.) In iron of medium hardness that is hardened during the change in state of the iron, a fifth well-characterised elemental constituent can be distinguished, named by Osmond troostite. If an iron containing 0·45 per cent. of carbon be heated to 825° C., cooled to 690° C., and then hardened, etch-polishing shows both the hard martensite and soft ferrite, with another material of medium hardness between them. They differ from sorbite, and represent a transition form between soft iron and hardened steel. Like sorbite, troostite is only known by its microscopic reactions, its chemical nature being undetermined.

To repeat briefly, a systematic examination of a sample of iron would thus consist of (1) relief-polishing, (2) etch-polishing, and (3) etching with iodine tincture.

On etch-polishing with French chalk the elemental constituents, martensite excepted, separate into two groups : (a) non-coloured—ferrite, cementite, and martensite ; (b) coloured—martensite, troostite, and sorbite. Martensite assumes only a yellowish colour, and is distinguishable by its crystalline form. It is a little difficult to distinguish it at first from perlite. Ferrite and cementite differ extremely in their hardness, and while the former will have been largely removed, the latter will stand out markedly. Troostite

colours less readily and more slowly than sorbite; but the true method of distinguishing them lies in the fact that troostite accompanies martensite, while sorbite is found with cementite in perlite.

By etching with iodine-tincture two groups are again divisible : (a) non-coloured—ferrite and cementite ; (b) coloured—sorbite, troostite, and martensite, the latter varying both in depth and tone of colour according to the percentage of carbon and to the quantity of iodine tincture used.

T. Andrews * publishes reproductions of microscopic sections of broken rails and axles, and gives details of the measurement of the internal cavities, the cause of which he ascribes to the presence of sulphur.

A. E. Seaton † discusses the causes of mysterious fractures in the steel used by marine engineers as revealed by the microscope, with special reference to a steel shaft used from 1883 to 1895, when it broke. This shaft was made of Siemens steel, and the metal was specified to contain 0·2 to 0·5 per cent. of carbon, and to have an ultimate tensile strength of not over 30 tons per square inch, with an elongation of 25 per cent. in five inches. The author is sceptical of the sufficiency of the fatigue theory as an explanation when stresses are far below the elastic limit. The broken section was investigated by J. O. Arnold. Analysis showed—

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
Exterior .	. 0·310	0·037	0·828	0·058	0·055
Interior .	. 0·470	0·031	0·986	0·167	0·150

These show that the ingot must have been cast very hot and that liquation ensued. Originally the composition was unsatisfactory and the steel was too hard. On microscopic examination the centre of the shaft showed that it consisted essentially of a series of "steel" cells surrounded by irregular and sometimes broken cell walls of "iron." In the exterior section the "iron" predominates and the junction lines are sharp. The sulphur in the interior occurs generally in the iron areas in three forms, as isolated globules or irregular masses, in smaller globules forming an irregular train, and as successive elongated streaks. The latter form is most dangerous, and the flaws probably gradually worked outwards. Such degradation pro-

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* *Engineering,* vol. lxi. pp. 91-92, with three illustrations.

† Paper read before the Institution of Naval Architects, March 26, 1896 (advance proof), with illustrations.

ceeds without visible indications, but boring out the centre renders the shaft much safer.

F. Osmond * has published a paper on the application of microscopic metallography to the manufacture of steel rails, translated from a memoir by A. Sauveur communicated to the Chicago Congress, to which he has added a number of notes.

Magnetic Properties of Iron.—According to I. Klemencic, when a current traverses an iron wire the molecules tend to arrange themselves in circular chains round the axis. This gives rise to strong extra currents at break. The magnetic susceptibilities are different along and round the axis. In soft iron the former exceeds the latter, whereas in Bessemer steel the circular susceptibility is the greater.

Nils Grane † describes a novel method of determining the temperature at which iron becomes non-magnetic. An iron wire is held by an electro-magnet, and heated by a current traversing it until it falls off. The temperature is then found by catching the wire in a calorimeter. Under the conditions of the test, the temperature at which the change takes place is not constant. It increases with the strength of the magnet, varying between 735° and 831° C. For nickel the figures are 368° and 481° C.

M. Maurain ‡ discusses the measurement of the energy dissipated in iron due to hysteresis. The amount of heat generated in a sample of iron when subjected to an alternating magnetic field is measured by enclosing the iron inside a cylindrical glass reservoir furnished with a capillary tube. This cylinder is filled with alcohol, and placed within a long magnetising coil. The reservoir being carefully protected from the heat generated by the passage of the current through the magnetising coil, the quantity of heat developed in the iron is deduced from the amount of the expansion of the alcohol. The development of heat due to Foucalt currents is almost entirely prevented by using a bundle of very fine wires. The curve which gives, as a function of the time, the position of the surface of the liquid in the capillary tube during an experiment consists of a straight line until the losses of heat due to radiation and conduction through the walls of the reservoir become appreciable, when the line becomes curved. A preliminary experiment

* *Annales des Mines*, vol. viii. pp. 153–177.
† *Acta* of Lund University; *Beiblätter zu den Annalen der Physik*, vol. xix. p. 915.
‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxxii. pp. 228–230.

having indicated the form of this curve, in the final measurement care is taken that the observation does not extend beyond the straight part of the curve. The author finds that the quantity of heat developed during one cycle diminishes as the rapidity of the alternations increases. This diminution, however, becomes smaller and smaller as the frequency increases, and seems to be practically independent of the magnitude of the magnetising force. The author considers that the diminution observed is probably due to the screening action of the outside layers of the iron, and some experiments on which he is now engaged seem to favour this view.

In a lecture delivered before the Engineering Society of King's College, London, on February 14, 1896, E. Wilson * discussed the time rate of growth of magnetisation of iron and its importance to the electrical engineer.

At the Royal Society's conversazione on May 6, 1896, Professor Ewing exhibited a new apparatus for measuring the magnetic permeability of iron or steel. The new apparatus allows measurements of permeability to be made with samples in the form of short rods, and greatly simplifies the process. It acts by making a magnetic comparison between the rod to be tested and a standard rod, the magnetic quantities of which have been determined beforehand. The two rods lie parallel, with magnetising coils wound on both, and their ends are joined by two short yokes. The two form, with the yokes, a single magnetic circuit. When the induction in both rods is the same, the yokes are at the same magnetic potential, and in that case a magnetic detector placed between them is not deflected. The number of turns in the magnetising coil of the rod to be tested is varied until this is the case. Thus a comparison is made between the magnetising forces H_1 and H_2 required to produce the same induction B in both rods. The B–H curve for the standard rod being known beforehand, the curve for the other rod is determined. The magnetic detector, which shows when the two rods have the same induction, consists of a compass needle placed in a gap in an iron bar joining the two yokes. From its analogy to the Wheatstone Bridge, the author proposes to call the instrument a Permeability Bridge. It forms a companion instrument to the Hysteresis Tester exhibited last year. In the instrument exhibited the samples are in the form of turned bars. Another arrangement of the yokes allows strips of sheet metal to be tested for permeability in the same way.

* *Engineering*, vol. lxi. p. 267.

Thermal Conductivity of Iron.—L. Holborn and W. Wien [*] review the determinations of the thermal conductivity of metals hitherto published. The mean of the values given is—

Copper	. 0·918
Iron	. 0·156
Steel	. 0·062 to 0·111
Zinc	. 0·292
Tin	. 0·150
Lead	. 0·079

Beglinger [†] gives the results of determinations of the thermal conductivity of iron and steel of various kinds by means of thermo-electric measurements.

Transmission of Light by Iron.—Experiments by Le Bon [‡] show that ordinary light rays will traverse sheet iron, and with long exposure photographic results may be obtained. A better result was obtained when a lead sheet was used as a backing to the iron plate than when the latter was used alone.

The Hardening and Annealing of Steel.—A. Le Chatelier [§] discusses at length the theory of the hardening of steel as enunciated originally by Charpy. He then passes to a consideration of the processes of hardening and annealing which are in use at French works. By Osmond's term, "negative hardening" is understood in France a method by which steel (ingot metal) is cooled at the ordinary temperature of from 750° to 800°, under conditions which, while they do not interfere with the alteration in the texture of the metal, yet do so as regards that degree of hardening which is marked by the presence of a large percentage of hardening carbon. If, for instance, soft steel is plunged from a temperature of 800° C. into boiling water, no hardening ensues, but the texture of the metal becomes fibrous, and the degree of brittleness is considerably reduced. In this way a sample of steel which has been heated either too long or to too high a temperature can recover all its former good qualities. In the opinion of Le Chatelier this method possesses such important advantages that every piece of steel which is subjected to mechanical treatment when hot should

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 45–47.
† *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1896, p. 33.
‡ *Stahl und Eisen*, vol. xvi. p. 271.
§ *Bulletin de la Société d'Encouragement*, vol. x. pp. 1336–1352.

be submitted to it. The process may, however, become dangerous in the case of objects with sides of such varying degrees of thickness that strains may readily result on this cooling treatment. In these cases it is customary to heat the object to be treated to 800° or 900°, and then to cool it as rapidly as possible to 600°, and then to allow it to cool down subsequently to the ordinary temperature quite slowly in air. The sudden cooling to 600° causes no hardening at all, but it produces a change of texture. In practice the process is carried out in different ways. Occasionally, as in the case of armour-plates at the Saint-Jacques de Montluçon Works, the objects to be treated are plunged into molten lead, and in others the oven doors are opened until the temperature has dropped to the necessary point. In others, again, the heating furnace has a movable bottom, and this is subsequently run out with the heated materials upon it, the latter then cooling down to 600° in air, when the bottom and the objects upon it are again run back and the whole allowed to cool down steadily. Though this arrangement has a high first cost, this is said to be justified by the good results obtained.

Another method is termed "double hardening." This consists in a preliminary hardening followed by annealing at a lower or higher temperature with a view to eliminate strains, and then again hardening. This double hardening does not, as Charpy has shown, affect the strength and extensibility of the material, but it eliminates the yield-point, a matter of occasional importance, as, for instance, in the case of springs. A spring hardened in the ordinary way is completely pressed together when the yield-point is reached, but with a double-hardened spring this is entirely different. As soon as the limit of elasticity is exceeded it suffers, indeed, a very slight deformation, but the limit of elasticity immediately increases again and the deformation ceases. This is especially of importance in connection with springs for railway waggons which are subject to frequent concussion. Another result of the double hardening, which also depends on this elimination of the flow of the metal, is a diminution in the brittleness.

Le Chatelier has found that in the case of iron wires the result of repeatedly applied slight blows is greater than that resulting from one sudden and heavy blow, a much increased elongation resulting before fracture. Considère had previously made somewhat similar experiments. The same effect resulted at very low temperatures. When, however, the wire is first submitted to the double-hardening process,

it is found to exhibit the same elongation with rapidly applied force as with a force slowly applied. In addition to this application in the case of springs, the method is also used at Le Creusot for guns and armour-plates. At other works it is used for numerous other purposes, and at the Indret Works it has been applied for the past two years in the case of all machinery made of steel of a medium degree of hardness.

A. Ledebur * discusses the hardening of steel. That steel could be hardened by plunging the heated metal into water was known in the earliest times, and Homer described it. The views that were held as to the causes of this hardening were, however, very remarkable. Not until the nineteenth century did these views begin to get clearer, and great attention has been devoted to it in recent years. Many points have been cleared up, but views diametrically opposed to each other have still to be brought into accord. The author refers in detail to Howe's paper on this subject,† observing that it still leaves the question undecided. Many fresh experiments, he adds, will be necessary before this can be the case, and in his opinion this will not be till the changes in state of the carbon are fully understood. He mentions the following case in point, which he believes has not yet been referred to in the literature of the subject, and is not mentioned by Howe in his monograph :— If a bar of hard tool steel is hammered until it has cooled down below a red heat, and then by rapidly repeated hammer blows is again raised to a distinct glow, which, as is well known, is by no means difficult, and is then allowed to cool down slowly in the ordinary way, a considerable portion of its carbon contents is converted into temper carbon, which, as a rule, is visible to the eye as a black seam, and which remains undissolved when the steel is dissolved in hot nitric acid. The steel has become softer and does not harden, or does so to a slight extent only, although its texture on plunging into water changes exactly in the same way that it would had hardening actually resulted, and the temper carbon can then no longer be detected by the eye on the fractured surface. Whether its presence can be detected microscopically is still uncertain, no experiment in this direction having as yet been made. Further investigation is necessary to answer the questions whether this change under such treatment always takes place, or if it does so only under definite conditions, and what is the lowest percentage of carbon at which this change in the

* *Stahl und Eisen*, vol. xv. pp. 944-949.
† *Journal of the Iron and Steel Institute*, 1889, No. II., p. 258.

state of the carbon takes place. The author has two such samples having their origin in different countries. Analysis showed them to contain—

Sample.	Hardening Carbon.	Carbide Carbon.	Temper Carbon.	Total Carbon.	Silicon.	Manganese.
I. Unhardened . .	0·92	0·92	0·72	1·64	0·29	0·47
II.:—						
(a) Unhardened . .	0·50	0·38	0·66	1·54	0·11	0·31
(b) Heated to redness and plunged into water . . .	0·52	0·34	0·63	1·49	Not determined.	Not determined.

Sample (b) possessed completely, as has been already pointed out, the finely granular texture of hard cast-tool steel, but could be filed with quite the same degree of readiness as the same metal in its unhardened condition. It is probable that the same effect as that produced by rapid hammering would result from long-continued heating ; and the author considers it to be possible that mechanical treatment can of itself, under certain as yet unknown conditions, either directly bring about changes in the state of the carbon, or at least favour such changes.

The Influence of Cold on Iron and Steel.—M. Rudeloff[*]

observes that an investigation that was undertaken at the Charlottenburg Testing Institute on behalf of the Wilhelmshafen dockyard afforded an opportunity for investigating the influence exerted by intense cold on the physical properties of iron and steel. The lowest temperature reached in the experiments was –80° C. These experiments consisted in tensile, bending, and riveting tests at the ordinary temperature, at –20° C. and at –80° C., and the samples tested included round rivet iron rods 1 inch in diameter ; open-hearth ingot angle iron of 3·94 by 3·94 inches by 0·55 inch in section, and basic steel from Rothe Erde of similar dimensions ; rolled weld iron, angles, 3·94 by 2·56 inches by 0·35 inch ; spring steel, round bars of 0·98 inch diameter ; similar cast steel ; and hammered weld iron also of the same dimensions. For the riveting tests cylinders were used equal in diameter to their height, this varying from 0·31 to 0·79 inch, according to the thickness of the

* *Mittheilungen aus den königlichen technischen Versuchsanstalt*, vol. xiii. pp. 197-218, with fourteen illustrations.

metal examined. Each of these received, as a rule, ten blows of similar force. The various testing methods used are described. The tests at –20° were effected by the aid of a freezing mixture of ice and salt, and those at –80° by the use of solid carbonic acid. During the tensile tests the test-pieces remained continuously exposed to the action of the freezing mixture, but in the riveting and bending tests the test-pieces were removed from the freezing mixture, but returned to it for periods of fifteen minutes in duration, this return in the case of the riveting tests taking place after every blow. The results obtained are tabulated, and show that, by cooling, both the elastic limit and the tensile strength are increased, higher values resulting at –80° than at –20°, and at –20° than at –18° in every kind of metal examined. As the temperature falls to –20° the change in the limit of elasticity is comparatively slight as compared with the change which takes place beween –20° and –80°. On the other hand, the ultimate tensile strength is relatively more affected by diminishing the temperature down to –20° than it is subsequently. The elongation at fracture diminishes with increasing cold in every instance, the hammered weld iron alone excepted. This showed an increase. In comparing the various kinds of iron and steel with each other, it is found that open-hearth ingot iron was more affected in the tensile tests at –80° than any other, as will be seen from the following table :—

Metal.	Tested at – 80° C.		Diminution in Elongation on 3·54 Inches.
	Increase in Limit of Elasticity.	Increase in Ultimate Tensile Strength.	
	Per Cent.	Per Cent.	Per Cent.
Open-hearth ingot iron . . .	23·8	11·9	30
Spring steel	14·7	9·3	32
Hammered weld iron . . .	17·6	8·6	(+9·4)
Basic steel	11·5	6·5	13·2
Cast steel	6·8	6·1	18·7
Soft rivet iron	5·9	7·5	14·1
Rolled weld iron	3·2	7·5	5·2

It was observed that in every kind of metal the power of flow of the metal at the limit of elasticity increased with increasing diminution of temperature down to –80° C.

The riveting tests showed that the shape of the material was the less affected by the blows given to it, the lower had been the temperature to which it had been cooled. That is to say, not only had the

power of elongation in the tensile test been diminished, but the resistance to change of shape under percussive force had been increased, although the two were not altogether affected in a parallel manner. This alteration amounted in the rivet-tests to as much as 8 per cent. at –20°, and to 23 per cent. at –80°. The order in this connection of the various kinds of metal examined was as follows :—Hammered weld iron, rolled weld iron, basic steel, spring steel, cast steel, open-hearth iron, and rivet iron.

The bending tests showed that, as a rule, cooling to –20° exerted only a slight influence on the bending capacity of the metal, and cooling to –80° similarly affected this but little in the case of the soft rivet iron and the rolled weld iron, but the bending capacity suffered at this lower temperature in the case of each of the other metals examined, the greatest influence being shown in the case of the cast steel and the spring steel. Next to these came the open-hearth ingot metal and then basic steel, the effect being about the same with each of them. The three kinds of weld iron showed the greatest resisting power. It is noteworthy, however, that the open-hearth metal and the basic steel, despite the deteriorating action of the temperature of –80° C., still showed throughout greater bending power than did either the rolled or the hammered weld iron, and they were not exceeded in bending capacity by even the soft rivet iron.

In an editorial review of the experiments of Steiner and of Dewar on iron at very low temperatures, *Stahl und Eisen* * gives the various results in tabular form. Steiner's tensile tests made on open-hearth, basic, and weld iron, at temperatures varying from –50° C. to + 25°, showed that extreme cold diminished the elongation but increased the tensile strength and elastic limit. The three kinds of metal were about equally affected. In the bending tests some damaged pieces became extremely brittle, while undamaged specimens gave much more favourable results. The more the metal had been subjected to mechanical treatment the less did it appear to be subject to the influence of cold. Dewar's experiments were in part performed at the extremely low temperature of –182° C., and both wires and cast pieces were examined of iron, soft steel, and a number of other metals and alloys. A great increase in the mechanical strength of the metal results, zinc alone excepted. The magnetic moment of steel magnets increases by from 30 to 50 per cent. by cooling to –182°. The elasticity is also greatly increased at this low temperature.

* Vol. xvi. pp. 158–160.

B. F. Spalding * shows that a variation of temperature in any range may be made available for producing useful effects without changing the chemical nature of steel. A number of instances are cited to illustrate this. For high temperatures, the effects of chilling on draw-plates for wire; for very low temperatures, the increase of strength in Dewar's experiments; and in middle regions the experiments of Metcalf, Langley, and Williams are given as examples.

The Relation between Temperature and Grain of Steel.—

A. Sauveur and H. M. Howe† have determined the relationship between the size of the grain and the temperature to which it has been heated. The steel used contained 1·10 per cent. of carbon, 0·02 of silicon, and 0·41 of manganese. It was in bars $\frac{5}{16}$-inch square, slowly cooled, polished, and etched. The area of the magnified grains was measured, and the results are plotted to ordinates of temperature and size. Approximately all fall on a straight line, with one exception, for which no reason can be given.

The Dilatation, Annealing, and Welding of Iron and Steel.—

T. Wrightson‡ deals with investigations of some of the physical changes which occur in iron during its passage from the homogeneous molten state to the solid and more permanent condition. With regard to the alleged floating of solid iron upon molten iron of the same kind, the author has found that if the piece of solid iron was lowered into the liquid metal by means of an iron fork, it always descended with the fork, but in a few seconds left the prongs and floated to the surface. For some time the sphere continued to rise above the surface until, at such a temperature that it melted, it quickly joined the molten metal. On first sinking, the ball proved itself to be denser than the liquid iron. It then expanded and became considerably less dense than the liquid ; and lastly, a reversal took place, and the ball in melting became of the same density as the liquid. The assumption that dilatation was con-tinuous and uniform during the passage from the liquid to the solid state was therefore erroneous. In order to eliminate the errors due to the emergence of the floating body above the surface of the molten metal, the author used for subsequent experiments an instrument by which the specific gravity of a 4-inch cast iron ball, completely sub-

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* *The Age of Steel*, vol. lxxix. No. 8, pp. 10–11.

† *Engineering and Mining Journal*, vol. lx. p. 537.

‡ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 163–271.

merged in the metal, could be observed and continuously recorded. A specimen of the record obtained from the apparatus was given. Experiments upon grey Cleveland iron showed that the specific gravities of the cold solid iron, molten iron, and of plastic iron were 6·95, 6·88, and 6·50 respectively, and that in passing from the solid to the plastic condition, the iron underwent an increase of volume of 6·92 per cent., followed by a quick contraction as it became liquid.

The order of experiment was afterwards reversed, and the change of volume was measured as the molten iron solidified. Into two spherical moulds of dried loam, 15 inches in diameter, was poured in one case Cleveland white iron, and in the other Cleveland grey iron. A few minutes later, the top half of the mould was raised, and the diameter of the congealed surface was measured with callipers. This was repeated at intervals. The results afforded qualitative confirmation of the other experiments. The early consolidation of the outer layers, however, by impeding the free expansion of the interior, prevented quantitative agreement.

The fluid metal first entirely filled the mould. An expansion of the outer layers then took place as the metal became plastic, the diameter of the ball therefore increasing. The liquid interior, not having commenced to expand, sank in the hollow shell formed by the cooling and expanding layers of the outside, and thus formed a cavity at the top, which was shown in a photograph of the cross-section of the ball. The metal round the inner surface of the top cavity then hardened, and the interior liquid metal expanded gradually towards the centre; and, by its pressure on the soft outer envelope, also tended to increase the diameter of the ball. This action continued until the outer layers arrived at such a temperature that they should contract, when a contest arose between the contracting force of the fast-thickening outer layers and the expanding force of the interior as it in turn became plastic. When these forces balanced each other, further expansion was arrested. After this point in the cooling had been reached, the outer layers contracted as far as their condition would allow, but not to the full natural extent, as, while the outside was in a state of tension owing to the swelling of the interior, fresh layers of plastic and solidifying metal had been built up in the interior. By the time contraction had commenced, these had formed an arch of many courses under different degrees of tension; and such a structure tended to prevent the free contraction of the whole mass. The interior of this enlarged vessel then contracted and drew away principally from the

upper part, owing to the mass of plastic iron tending to gravitate to the bottom of the ball.

The specific gravity of the material was found to be, at the surface of the top cavity, 5½ inches above the centre of the sphere, 6·95, at the centre of the sphere, 7·13, and at points, 2⅜ inches, 4¾ inches, and 7⅛ inches below the centre, 6·87, 7·08, and 7·15 respectively. The results of further experiments on the buoyancy of solid rolled low-carbon steel showed that it followed the same law as cast iron. It appeared, therefore, that the physical changes from liquid to solid, as from solid to liquid, were similar in grey iron, white iron, and low-carbon steel.

These changes in volume during solidification seemed to account in a measure for the treacheries which so frequently appeared in structures of cast iron and steel. The same operations, as described for the cooling of a 15-inch ball, were at work in the cooling of all castings. In their design, therefore, forms in which extreme initial strains were likely to be generated should be avoided. The method of cooling should also be favourable to the avoidance of such strains being set up, as cast-iron plates of good material, after being cooled, sometimes suddenly and spontaneously broke into pieces, on account of improper cooling.

The process of slow cooling or annealing anticipated this action by causing the fall of temperature, and consequent change of volume, to be so slow that the groups of particles in the casting had time to accommodate themselves to their changing condition of volume, and thus to minimise the internal strains. In every cooling body the radiation of heat from the exterior was more rapid than from the interior.

The most important condition in slow cooling appeared to be that the difference of temperature at any time during cooling, between the hottest and coldest particles, was reduced to a minimum.

In view of the apparent analogy between the expansion of cast iron in cooling from the liquid to the plastic condition and the expansion of water in cooling from 4° C. to 0° C., the author had undertaken experiments to ascertain whether the welding of iron could be attributed to action similar to that producing regelation in ice. To identify the two phenomena, it must be proved that the surfaces of the iron at the moment of welding contracted with increase and expanded with decrease of temperature. But as, according to the reasoning of the late Dr. James Thomson, matter possessing this property must also

be cooled by impact or pressure, the identification would be complete if this collateral property of the cooling of welding iron under pressure could be demonstrated.

In the author's experiments, which were carried out at the Mint, with the aid of Professor Roberts-Austen, the temperature at the welding surface of iron heated in an electric welding-machine was taken by a Roberts-Austen recording pyrometer. The results were given of a series of five experiments, in three of which a fall of temperature, ranging between 19° C. and 57° C., had resulted from the application of pressure, at temperatures of between 1300° C. and 1420° C. The thermal expansion of iron was therefore negative between 1300° C. and 1420° C.

The theory of regelation in ice was founded on the fact that the melting-point was lowered by pressure. This held good also for iron, in which case, however, there were increasing degrees of mobility between the temperature of 1400° C., and that of melting wrought iron, 1600° C. When pressure was applied to a bar, *e.g.*, at 1400° C., not only was the melting-point lowered, but the mobility of all lower temperatures within the critical condition was increased.

The Effect of Vibration on Wrought Iron.—E. B. Grub[*] makes some quotation from the works of W. Fairbairn to show his opinion on the effect of vibration on wrought iron; in reply, R. W. Raymond shows that these passages do not prove conclusively that Fairbairn believed in crystallisation as an explanation of the fracture. Besides this, the matter had not been studied to any extent before 1870. Sudden fracture in any case produces an appearance having a crystalline form; and though some persons seek to argue that the appearance of a fracture in iron that has undergone much vibration is not exactly similar, yet the whole story is summed up in each case in the words, "the fibres break."

The Mobility of Molecules of Cast Iron.—A. E. Outerbridge[†] shows that repeated shocks, instead of making cast iron brittle, have exactly the opposite effect, and in fact produce a molecular annealing at ordinary temperatures which will release strains in castings precisely as does slow cooling in heated ovens. As long ago as 1883 the author

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[*] *Transactions of the American Institute of Mining Engineers.* Pittsburgh meeting, 1896 (advance proof).

[†] *Ibid.*

noticed that chilled cast iron wheels rarely cracked after some service, but lasted until worn out or condemned if they did not crack when comparatively new. In 1894 a large number of transverse test bars were cleaned from sand by tumbling them in a barrel, and it was found that they gave results higher by 10 to 15 per cent. as compared with test bars cleaned with the brush. Careful experiments were made to discover the cause of this behaviour, and it was found that it was certainly due to the repeated blows endured in the barrel. Six bars, as a crucial test, were subjected to 3000 taps, each on one end of the bar only, with a hand hammer, and all these bars showed a gain in strength. The experiments showed incidentally that cooling strains and consequent weakening exists in the smallest castings, and that in 1-inch test bars the weakening sometimes amounts to more than ten per cent. The improvement by shock depends to a certain extent on the number and force of the blows, and to a still greater extent on the grade of cast iron tested. Greater relative difference is found in hard mixtures or strong iron than in soft mixtures or weak iron. Greater relative difference is found also in 1-inch than in ½-inch bars, and somewhat greater difference in 2-inch than in 1-inch bars. After this was decided, attempts were made to find the number of blows and the force required to relieve cooling strains, and it was seen that the impact testing-machine is itself a means of molecularly annealing test bars. Thus a bar annealed by subjecting it to ten to fifty blows of a tup falling from half the height necessary to break the bar in the first instance would endure two to fifteen blows from the original extreme height. Similarly bars treated in a tumbling barrel endured five to twenty blows that would break an untreated specimen

It is pointed out that this molecular annealing differs from annealing by heat, as the carbon and chemical composition generally is not changed. It is the condition of strain set up during cooling that is relieved. From these statements it is deduced that castings subject to severe strains in actual use should never be suddenly tested to the severity of intended service, and strong iron castings or castings of irregular section should be subjected to gradually increasing shocks, until the strains are relieved. The numerical results of a number of tests are appended.

Uniformity in Methods of Testing.—In 1891 an official commission was appointed in France to deal with the question of uniformity in the methods of testing. It was composed of members from the governmental departments, from the railways, and from manufac-

tories. Forty-three reports dealing with metals, and thirty-one treating of materials other than metals, were presented.*

The methods of investigation are collected under the heads of physical, chemical, and mechanical tests. Physical testing has as its object the evaluation of metal with regard to its physical characteristics and the study of changes produced in its constant properties by purely physical causes, both in its preparation and in its use. There are three principal methods, namely, inspection, determinations of constants such as density and electric conductivity, and the investigation of critical points of temperature with their variation under work or under heating and cooling. External inspection is obviously not capable of giving very exact results, but fractured surfaces are certainly a guide, so the classification into nine species as adopted at Bourges is borrowed. The appearance of brass after reheating offers certain indications, and investigation in this direction as regards steel is under consideration. The value of micrography is not yet determined, but references are made to Osmond's work on this subject, and it is hoped that the great interest now taken in it will lead to good results. Sound or resonance tests are also mentioned in connection with the determination of flaws. Rules already in operation for the estimation of density and conductivity are repeated, and then the work of Osmond and Charpy on critical points and on tempering is briefly reviewed.

The question of chemical testing is fully dealt with in a valuable report on the subject by A. Carnot.

The major part of the report, which includes the third and fourth sections, is devoted to mechanical testing, the third being devoted to general matters and the fourth to a detailed examination of the different tests. The first chapter of this third section sets forth the general scheme of treatment, discusses the various circumstances capable of influencing results, and indicates the points which bear on the question of uniformity. It also shows the means adopted for securing consistency in the interpretation of separate results. Trials with test pieces will evidently give more uniform results than other methods, and it is in this direction that researches have been made. Even on these lines it was found impossible to include all methods, so that further consideration of some of them has been postponed. Methods of testing in which the stress is applied gradually give more complete uniformity than those in which sudden action occurs. Most

* *Commission des méthodes d'essai des matériaux de construction,* 4 vols. Paris. A copy of this work is in the Library of the Institute.

of the members consider that tensile tests give more uniform results, and they may be used as a standard of comparison, but this opinion, however, is not unanimously held. The effect of inequality of structure may have great effect in test-pieces of small size, in cast metal for instance, as is seen in purely physical tests. This variation affects not only the ultimate strength but also the elongation in a still more marked degree. Even before the constriction appears the elongation is not uniform over the body of the test-piece, and the breaking load is not strictly proportional to the cross section. Barba has shown that variations in elongation may range from 15 to 20 per cent. before rupture and still more afterwards. These differences, according to Savage, occur in a still more marked degree between test-pieces from different samples. In spite of this the tensile test cannot be condemned altogether for such large variations when much work has been put into the metal so as to produce greater homogeneity, and if it does show the occurrence of irregularities somewhat too faithfully it still has an exactitude that other methods cannot attain. It must not be forgotten that this method demands numerous and expensive test-pieces, and that the results are local and cannot give the average value of any piece of work. Other methods for this purpose must be sought for, and amongst these may be mentioned shearing and punching, but these are considered later.

The second chapter deals with the preparation of test-pieces, and sets forth numerous precautions, but these may be summarised by saying that recourse must never be had to any operation which can possibly modify the quality of the metal.

The influence of temperature and time is treated in the two following chapters, and for these the researches of A. Le Chatelier are referred to. Above 100° C. the metal is very sensitive, and small deformations produce alterations which persist at ordinary temperatures. This is of especial interest in view of the increasing pressures used in boilers. Below 0° C. brittleness increases, especially under milder efforts, but a heavier blow is required to produce the same deformation. The recommendations, therefore, relate principally to falling weight tests, as tensile tests are only slightly affected. Considère and A. Le Chatelier have shown that deformations produced by long-continued action do not increase in proportion to the time, but approach a limit approximating to those produced in the ordinary way. On small sections, such as wire, the ultimate strength is somewhat greater if the load be quickly applied than is the case with larger test-

pieces in which the heating effect of a quickly applied load reduces the strength. The influence of time on elongation is even less marked than it is on the strength as long as the ordinary temperature is maintained, and this tends to shew that the question of time, apart from the heating effect, may be neglected.

The fifth chapter is devoted to testing-machines, which are divided into two classes, according as the action is slow or abrupt. In the first class, in tensile testing-machines, there should be a measuring appliance, independent of the power-transmitting mechanism. The precautions to be taken in the construction of lever and hydraulic machines are indicated, and reference is made to the necessity for easy observation and for verifying the results. The amount of precision necessary is given as $\frac{1}{250}$ at half the maximum load. Many recommendations are given with regard to machines for compression, bending, torsion, and other tests. Machines acting abruptly are generally falling-weight appliances, and in these all absorption of power, apart from the blow, must be guarded against. The tup should therefore fall vertically, with minimum friction, on the guides, and its centre of gravity should be as low as possible. The anvil should be 15 to 20 times as heavy as the tup.

An examination is then made of the factors that have to be measured, and this necessitates a discussion of the elastic limit. On tracing the behaviour of a test-piece up to its rupture, it is seen that, as a rule, it is sufficient to observe the load at the point when it remains stationary while the piece sensibly elongates. This is called the apparent limit. Instead of this the elongation may be watched as it changes, from the time when it is proportional to the load to the time when it becomes more rapid, according to a different law. The Committee was unable to find a practical method for determining exactly the theoretical limit, and they distinguish three points: The theoretical limit above which deformation ceases to be temporary; the proportional limit, corresponding to the point when the deformation ceases to be proportional to the load; and the apparent limit, corresponding to the point when the deformation takes an increased value without augmentation of the load.

The seventh and eighth chapters are devoted to mechanical and technical nomenclature, and to definitions of the various properties in question, but this matter is still under discussion.

The following section treats in detail the various methods of testing under several classes. By far the most attention has been paid to the

tensile test. Amongst the matters dealt with are the precise obser-
vation of the elastic limit; variations presented under different con-
ditions of testing; questions relative to the measurement of elongation;
the difference between general elongation and local elongation due to
striction; the relation between length and cross section of the test-
piece; the influence of the shape of the ends of a test-piece, and the
methods of its attachment; special recommendations for soft metals,
and so on. Amongst these points the most important undoubtedly
is the statement that test-pieces geometrically similar in form give the
same relative elongations. From that it is decided to use the equation
length squared equals 66·66 times the section to obtain correspond-
ing test-pieces of circular section. Similar formulæ are given for other
sections.

For crushing-tests the dimensions of short test-pieces are specified,
and the precautions to be taken when using long test-pieces are also
dealt with.

Transverse tests for cast iron and steel, and for finished materials
such as rails, are also discussed, and the line taken practically follows
that now in general use.

Bending tests are considered under three heads, according as the
piece is doubled back on itself, bent over a mandrel, or bent into a
free curve without a mandrel, and the rules proposed are intended to
secure simplicity.

Torsion tests have been studied scientifically, but no rules are set
forth with regard to this, nor to shearing and punching. Since the
consideration of these methods, however, the valuable researches of
Fremont * have been published.

In another memoir C. Fremont † gives the results of a detailed study
of punching and shearing. The subject is dealt with under the follow-
ing heads: (1) measurement of the maximum effort developed in each
of the two operations, and registration of the diagram showing the
work expended; (2) observation of the deformations of the metal
during the course of their operations; (3) discussion of the effect of
play in the matrix; (4) investigation of the best form of punch; (5)
investigation of the cause of the deterioration of the metal under the
action of these operations; and (6) examination of the use of these
operations as means of testing metals.

The second class of tests are impact tests, or those in which sud-

* *Journal of the Iron and Steel Institute*, 1895, No. I. p. 470.
† *Memoires de la Société des Ingénieurs Civils*, vol. xlix. pp. 48–115.

denly applied force is used. These include transverse tests, superficial penetration, and perforation by a projectile. The latter relates only to armour, and is not considered at length. Bending tests under a falling weight are most frequently employed in practice, and bring into play a resisting quality quite different to that which resists slow and continuous action. The results obtained depend very largely on the conditions of performing the test, so the shape of test-piece, the supports, and the tup, are defined in detail. Superficial penetration, as a test, is scarcely known, although it is of much interest. The method has been investigated by Martel.

The third class of tests relates to hardness and brittleness. Included, also, are plasticity and resistance to wear. But little is to be expected from the sclerometer, but a new test proposed by Considère is of interest. This consists in bending, after cold hammering under a punch. The angle obtained before cracks appear is a good indication of brittleness.

The fourth class includes all the tests usually resorted to in the works. These are dealt with generally, as are also those of the fifth class, which includes all special tests performed with certain finished work, such as wire, cables, chains, rivets, tubes, &c.

Hudson Beare * briefly states the extent of the present knowledge of the mechanical testing of iron and steel, and indicates the lines upon which it is desirable that further advance should be made.

For commercial testing he advocates the use of flat specimens 8 inches long in the parallel part, and 1·6 inch wide for all thicknesses up to 1 inch. For turned specimens a length of 10 diameters is satisfactory, but in certain cases, such as in testing tyres and gun steels, this length cannot very well be obtained. In recording the behaviour of a test-piece, its previous history, so far as is known, should be stated, for unless its past treatment is known it is impossible to properly interpret the results obtained. The original dimensions of the bar should be stated, together with the yield point and maximum load expressed in pounds or tons per square inch. The extension, both on the whole length and on the 2-inch, including the fracture, should be recorded, the reduction of area being also stated. Complete data of this nature permit of a fair estimate being formed of the quality of the bar, and when combined with a chemical analysis, also afford useful information to the maker, as well as to the user of the metal.

* *Science Progress*, vol. iv. pp. 216-228.

Testing Machines.—Illustrations have been published * of the Riehlé automatic and autographic 100,000 lb. testing-machine. The machine is of the multiple lever type, and the power is applied by an upper movable crosshead raised and lowered by screws. These are driven at variable rates by means of several clutches in the gearing, and a friction feed is used for slow motion. The lower crosshead is connected to the multiple levers, on one of which the counterpoise is traversed by gearing, part of which consists of a usual frictional device consisting of a wheel held in contact with the face of a second wheel across which it can be moved so as to regulate its speed. Power is supplied to move the counterweight only when the beam rises, and completes a circuit which throws into operation an electro-magnetic clutch. By giving this lever a very small vibration, the poise may be kept very closely in balance with the stress.

The recording apparatus for torsion tests and other teaching appliances at the Bradford Technical College are fully described and illustrated.†

An illustration has appeared ‡ of a milling-machine for the rapid preparation of test-pieces. It will deal with pieces up to 19 inches in length, and from ¾ inch to 4 inches in breadth.

The Use of Punching and Shearing as Means of Testing.— L. Baclé and C. Fremont § have endeavoured to use diagrams obtained with the aid of the elasticimeter during the operations of punching and shearing metals, as tests of the resisting properties of the metals. They have found that with bars of the same metal the maximum ordinate of these diagrams is directly proportional to the thickness, and also that the breaking load in the operation of punching is seven-tenths of the load which would just break a rod of metal of the same diameter as the piece cut out.

Testing Cast Iron.—T. D. West ‖ gives detailed directions for moulding the 1½ inch round test bars for transverse tests, which he prefers to square ones for this purpose. The author comments upon the largely increased attention that has only recently been devoted to the chemical testing of pig iron, and predicts that shortly the same

* *Iron Age,* vol. lvi. pp. 740-741.
† *Engineering,* vol. lxi. pp. 371, 465.
‡ *American Manufacturer,* vol. lviii. p. 512 ; *Iron Age,* vol. lvii. p. 869.
§ *Comptes Rendus de l'Académie des Sciences,* vol. cxxi. p. 713.
‖ *Transactions of the American Institute of Mining Engineers,* Pittsburgh, 1896.

interest will be taken in physical tests.   It is pointed out that a use may be found for all kinds of iron.

Standard Tests for Cast Iron.—T. D. West * urges the necessity for a standard of physical tests for pig iron.   At the present time there is no uniformity in the methods of testing, so that it is not possible to compare results from different places, and in some cases no tests are made at all.   It is not clear at present what relation there is between chemical composition and physical properties, but probably the latter will ultimately be closely estimated from the former.   The first point mentioned is the value of remelting samples of the furnace casts.   This may be done in a small cupola, and it cannot but aid the advance of research, serve as a check on chemical analysis, and often as a protection to the furnaceman by enabling him to learn what the founder can do in changing the character of iron.   A small cupola that has been used by the author was made of an old shell, 12 inches in diameter and 30 inches high, and a cast could be made ten minutes after the iron was charged.   The author then proceeds to describe in detail a plant used for making the tests, and he gives a complete series of illustrations of the apparatus and test-pieces.   The plant consists of an Olsen transverse testing-machine, a cupola, two flasks, and chill pig moulds with a test-bar pattern and mould board.   Its total cost need not exceed £20.   The author adheres to his preference for round test-pieces cast on end for transverse and tensile tests, and the method of making the moulds for these and for the fluidity test-strip, together with all the precautions to be taken in casting them, and in pouring the metal into chill moulds for testing chill and contraction, are fully set forth.

Shrinkage and Contraction in Iron Castings.—T. D. West † differentiates between the terms shrinkage and contraction as applied to iron castings, restricting the former to the decrease in volume requiring feeding while the metal is still liquid, and the latter to the decrease of volume after solidification.   The two are separated by the expansion at the moment of solidification.   It is found that hard grades of iron shrink more than soft grades, and this, the author finds, may be ascribed to the fact that these hard grades expand most on solidifica-

* *Transactions of the American Institute of Mining Engineers*, Pittsburgh Meeting, 1896 (advance proof).
† *Ibid.*

tion. The expansion of the shell which forms thus accounts for the differences in the shrinking of the still liquid interior of the casting. This greater expansion of hard irons, as discovered by the author, is contrary not only to general opinion, but also to current explanations of expansion which ascribe it to the segregation of graphite. No definite explanation can, however, as yet be given. The apparatus used for determining the expansion and contraction is described and illustrated.

Remarkable Fracture of Cast Iron.—Illustrations [*] have been published of a remarkable fracture of a cast iron mullion. The section might be described as a double channel or a ⊥ with a shorter flange on each side of the rib. During the winter it filled with water which froze solid, and a portion of the outer $\frac{3}{8}$-inch flange, 51 inches long, was forced out, taking the shape of an almost perfect arc. The broken piece remains tightly wedged in between the uninjured portions of the flange. The fracture is almost a perfectly straight line. The fractured part is forced out $2\frac{1}{2}$ inches in the centre, and the immediate cause of the fracture was of course the freezing of the water, but the permanent elongation can scarcely be due to this. It would appear that the section which broke away must have been under initial compression, so that it sprung out when cracked away by the expansion of the ice.

Cast Iron Segments for Lining Tunnels.—E. G. Carey [†] describes the use and manufacture of cast iron segments for lining railway and other tunnels. The tensile tests of the cast iron used in different instances showed $6\frac{1}{2}$ and 8 tons ultimate strength, and 2 tons at elastic limit. Transverse load tests in one instance gave 7 cwt. on an inch square bar on 3-foot centres, in another 28 cwt. on a one by two inch bar on 3-foot centres. For the Glasgow district subway 120,000 segments, weighing about 20,000 tons, were required. These were mostly about 4 by $1\frac{1}{2}$ feet in area, and were $\frac{3}{4}$ inch, 1 inch, and $1\frac{1}{4}$ inch in thickness. All of them were moulded on hydraulic machines. The process of moulding and of preparing the joints by milling the edges of the plates are fully described both for this and other tunnels, the plates and machinery being illustrated. The form of joints is also discussed.

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[*] *Engineering News*, New York, vol. xxxv. p. 216, with illustrations.

[†] Paper read before the Institute of Engineers and Shipbuilders in Scotland, through *Industries and Iron*, vol. xx. pp. 86-89.

Charcoal Iron for Chain Cables.—The following specification *
for charcoal iron for chain cables has been promulgated by the United
States Naval Department. The bars are to be homogeneous, with
not more than 0·1 per cent. phosphorus nor 0·03 per cent. sulphur.
Silicon and manganese must be low. Bars must be multiples of 20 inches
in length, with an inch added, free of fag ends, and in section 6 inches
by 1 inch, or 2 inches square, or 1½ inch square. The tensile strength
is to be 48,000 to 50,000 lbs., and elastic limit about 28,000 lbs. per
square inch,·with elongation of at least 30 per cent. on 8 inches, and
contraction of area 40 per cent. Bolts cut from 1 per cent. of the bars
rolled must stand bending parallel over twice their diameter in the
cold, or till the sides are close together when hot, without fracture.
Nicked and broken cold by slow bending, the bolts must show a fibrous
fracture. One per cent. of the bolts rolled to chain sizes will be made
into a chain of three links, and must show a strength of 158 per cent.
of the original strength. No cold rolled bars are permitted.

Tests of Iron and Steel at Watertown Arsenal.—The report †
of tests made at the Watertown Arsenal during the fiscal year 1894
has recently been published by the United States Ordnance Depart-
ment. A gun tube tested by hydraulic pressure showed a ratio of 1 to
3·55 between longitudinal extension and lateral contraction. A number
of railway axle tests are given. Music wire drawn from steel contain-
ing about 0·85 per cent. of carbon showed a tensile strength ranging
from 30,000 lbs. per square inch for larger sizes up to 462,870 lbs. for
No. 12 size. Two tensile tests of cast iron with the composition of the
metal were as follows :—

Tensile Strength. Lbs. per Square Inch.	Composition.					
	Carbon.		Manganese.	Silicon.	Sulphur.	Phosphorus.
	Graphitic.	Combined.				
34,450	2·279	0·366	0·353	1·024	0·118	0·496
30,200	3·166	0·297	0·653	0·940	0·029	0·511

Endurance tests were made with rotating steel shafts containing
0·16 to 1·09 per cent. of carbon under stresses ranging from 35,000 to

* *Iron Trade Review*, vol. xxix. No. 11, p. 5.
† "Report of the Tests of Metals." Washington, 1895.

55,000 lbs. per square inch. Under the lowest stresses the number of the revolutions reached into the millions, but the shafts failed at the higher stresses below this number, so that it is assumed that the limit of endurance for alternate tensile and compressive stresses is reached below loads of 40,000 lbs. per square inch. Tensile tests were made of annular specimens cut from the ruptured shafts, and showed a gain in thirteen specimens and a loss in three. Tests were also made to determine the actual stresses in rails traversed by rolling stock.

Tensile Tests of Basic Bessemer Metal.—A. Brovot * publishes the following test-results of basic Bessemer metal :—

Composition of Metal.			Tensile Strength.	Elongation.
Carbon.	Phosphorus.	Manganese.		
Per Cent.	Per Cent.	Per Cent.	Tons per Square Inch.	Per Cent.
0·07	0·06	0·42	20·70	35·0
0·09	0·07	0·40	20·76	31·5
0·09	0·09	0·47	26·67	27·5
0·10	0·10	0·42	26·09	24·0
0·12	0·12	0·43	27·55	27·0
0·15	0·15	0·52	25·33	26·5
0·11	0·19	0·47	24·63	27·0
0·11	0·24	0·60	29·78	26·0

The metal was in each case produced by an afterblow of short duration.

Iron and Steel for Wrought Pipe.—J. Stone † condemns the use of steel for wrought pipe, and prefers iron, as he finds that screw threads can be more easily made on iron, and stand better. The weld in steel is not so trustworthy as in iron, and the corrosion is greater. The author states that the Standard Oil Company have determined to use only iron for pipe. Their specification is quoted to show that they demand a tensile strength of 52,000 lbs. per square inch, elongation not less than 15 per cent. in 10 inches, and reduction of area not less than 25 per cent. The elastic limit is not to be below 25,000 lbs. Test-pieces are to be cut from the finished tube and tested without working or drawing out hot. A piece cut longitudinally must bend back on itself over a bar of its own thickness. A ring 2 inches broad

* *Stahl und Eisen*, vol. xvi. p. 55–56.
† *American Manufacturer*, vol. lviii. p. 44.

cut from the tube and split at the weld is opened out and pulled apart in the testing-machine. It should show a fibrous structure.

The Distinction between Iron and Steel. — H. Wedding[*] discusses the question, "What are iron sleepers?" He points out that while the chemist understands by the term iron the pure metal, in technical life the name iron is made to include all varieties of that impure commercial product. "Iron" columns are spoken of in contradistinction to others, of wood or of masonry, and yet these "iron" columns as a rule contain not more than 91 to 92 per cent. of iron, the following being a typical analysis :—

Carbon.	Silicon.	Manganese.	Phosphorus.	Iron.
2·88	3·21	1·86	0·90	91·15

It was formerly customary to divide "iron" into the three kinds, pig iron, steel, and wrought iron ; every kind with over 2·3 per cent. of carbon being termed pig iron, metal with from 2·3 per cent. down to 0·6 per cent. was steel, and with less than 0·6 wrought iron. With further progress in the processes of manufacture, the subdivision became valueless and more complete subdivision became necessary, with the result that some clashing of terms ensued. Thus, what in English-speaking countries was termed "steel," was in Germany also termed ingot iron and ingot steel. Finally, ingot iron and weld iron have become adopted as distinctive terms. As the exact limit between hardening and non-hardening metal is as a rule hard to distinguish, in Germany it was decided officially that all metal with a tensile strength exceeding 32 tons per square inch should be termed "steel," and all with lesser tenacity "iron." Numerous false designations are still in use.

Steel Rails.—R. W. Hunt[†] gives specifications for steel rails of heavy sections manufactured west of the Alleghanies, and generally discusses the manufacture of rails. In his opinion the sections adopted by the committee of the American Society of Civil Engineers are good, and promise soon to be generally adopted in America. If they fail to give good service, other causes must be sought for. Many changes have been made of recent years. Hot heats in the converter are strenuously avoided, greater care is used in teeming, ingots are seldom thrown on their sides before they are solid, soaking-pits are generally adopted, and liberal cropping is resorted to. The general finish of

* *Stahl und Eisen*, vol. xvi. pp. 160–165.

† *Transactions of the American Institute of Mining Engineers*, Atlanta Meeting, 1895 (advance proof).

rails is now much better, owing to inspection. It is, of course, impossible to obtain such good wear from heavy sections as from lighter ones, which can be worked so as to have finer grain in the head; but as the sections are increased, the hardness may be added to with safety. The value of silicon is now recognised, but phosphorus and carbon have to be carefully controlled. In the western states the standard of Bessemer ores until recently was 0·10 of phosphorus, giving 0·11 or even 0·12 in the steel rails; but the recent developments in the Mesabi region will enable the rails to be kept below 0·09 phosphorus, and in the future probably rail steel will be considered a special metal, and the blast-furnace charged accordingly.

The specification contains clauses relating to the section, length, finish, drilling, branding, chemical composition, tests, drop-tests, treatment of ingots, &c., cutting of blooms, heating, inspection, and No. 2 rails. The composition prescribed is as follows for carbon :—

Weight of section, lbs. . . .	70	75	80	90	100
Carbon, lower limit, per cent. .	0·43	0·45	0·48	0·55	0·62
Carbon, upper limit, per cent. .	0·51	0·53	0·56	0·63	0·70

The phosphorus is not to exceed 0·085 per cent., and the silicon is not to be below 0·10 per cent. For testing, two ingots 3 by 3 by 4 inches are cast from each heat, drawn down to ½ inch square bars under a hammer, and bent cold to not less than a right angle. The drop-test is made on a butt end of a rail, head or flange uppermost, on supports 3 feet apart, for sections up to 70 lbs., and 4 feet for heavier rails. The tup weighs 2000 lbs., and falls freely 16 or 20 feet for the two sections, and must not break them. Ingots are to be kept upright, and no bled ingots or chilled heats are allowed.

Lodge * discusses rail sections and wheels, and shows how more work is demanded from the rails, owing to the increased loads now carried. The various factors in rail construction that have been suggested and superseded are shortly traced, and the author recommends that the rails should be canted by cutting a rail-bed in the sleeper. By this means the rail head will offer a more extended bearing to the coned tread of the wheels, and its deformation is thereby reduced.

Tests of Boiler Plates.—Some tests have been published † of locomotive boiler plates at Harrisburg in Pennsylvania. The steel had

* Paper read before the Engineering Association of the South, January 23, 1896, through the *Engineering News*, New York, vol. xxxv. pp. 111-112.

† *Iron Trade Review*, vol. xxix. No. 4, p. 6.

to show a tensile strength of 22·2 to 26·6 tons per square inch, with an elongation of 25 per cent. on 8 inches, both longitudinally and transversely. With the exception of twenty plates ⅜ inch by 87 inches in width, the plates varied from ½ to ¾ inch in thickness, and were 74 inches in width and under. Of 104 plates rolled, three failed in tensile tests, and one in gauge. In elongation, the remainder averaged 27·46 per cent. elongation in the longitudinal direction, and 27·90 per cent. in the transverse direction, a result not usually expected. The metal was open-hearth basic steel, and showed on analysis :—

Carbon.	Phosphorus.	Manganese.	Sulphur.
0·165	0·014	0·37	0·27

Some alterations in the tests for boiler steel have recently appeared * in the United States. The form of the test-piece is prescribed, with a central plain part 9 inches long by an inch broad, curved off to the holding parts, which are 3 to 6 inches long by 1½ to 2 inches broad. The centre part is to be marked with light centre-punch marks to show 8 inches. The sample must show an elongation of at least 25 per cent. in a length of 2 inches, for thicknesses up to ¼ inch ; in a length of 4 inches for ¼ to $\frac{7}{16}$; in a length of 8 inches for $\frac{7}{16}$ to 1 inch ; and in a length of 6 inches for plates over an inch in thickness. Phosphorus is not to exceed 0·06 per cent., and sulphur 0·04. Bessemer plates are not allowed for marine boiler plates.

Testing Steel for Marine-Engine Construction.—Auscher † describes the methods in use for testing steel for marine-engine construction at the French Government Works at Indret.

Nickel Steel.—H. H. Campbell ‡ gives the results of some tests of nickel steel as compared with other steels. The analyses of these were as follows :—

	C.	Mn.	S.	P.	Ni.	Cu.
Nickel steel . .	0·24	0·78	0·027	0·032	3·25	...
Hard forging steel.	0·30 to 0·35	0·60 to 1·00	0·03 to 0·05	0·03 to 0·05	...	...
Forging steel. .	0·25 to 0·30	0·6 to 0·8	0·03 to 0·07	0·03 to 0·06	...	0·2 to 0·4

* *Iron Trade Review*, vol. xxix. No. 12, p. 9.
† *Annales des Mines*, vol. viii. pp. 564–589.
‡ *Transactions of the American Society of Civil Engineers*, vol. xxxiv. pp. 285-293.

Four tons of the nickel steel were made, cast into two ingots, and rolled to the various shapes mentioned. The manufacture is attended with increased cost on account of the nickel, but it is a question whether the enhanced strength will not more than counterbalance this in some cases, especially for the tension members of bridges. The tests were as follows :—

Shape of Member	Kind of Steel.	Ultimate Strength.	Elastic Limit.	Elastic Ratio.	Elongation in 8 Inches.	Elongation in 2 Inches.	Reduction of Area.
		Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Percentage.	Percentage.	Percentage.	Percentage.
Rounds	Nickel	86,015	63,575	73·9	20·19	34·00	46·3
	Hard forging	87,663	58,055	66·2	16·70	24·44	30·3
	Forging	78,066	51,793	66·3	23·94	....	52·0
Angles	Nickel	86,960	58,553	67·3	21·75	39·66	50·5
	Hard forging	87,820	54,153	61·7	19·25	34·83	43·3
	Forging	76,970	49,544	64·4	....	....	49·6
Universal plates, longitudinal	Nickel	85,773	58,410	68·1	21·08	39·25	52·0
	Hard forging	82,773	50,163	60·6	20·50	37·67	47·0
	Forging	78,996	46,654	59·1	26·78	....	52·1
Universal plates, transverse	Nickel	86,417	58,203	67·4	16·50	28·92	36·1
	Hard forging	85,173	50,000	58·7	18·83	23·17	27·4
	Forging	...	...	...	....	....	...
Sheared plates, longitudinal	Nickel	85,337	58,169	68·1	19·00	35·50	48·3
	Hard forging	85,012	50,000	58·8	22·10	39·40	48·4
	Forging	78,918	49,128	62·3	22·03	....	50·8
Sheared plates, transverse	Nickel	84,377	57,260	67·9	17·13	32·50	43·4
	Hard forging	84,327	50,000	59·3	21·71	37·00	41·3
	Forging	...	...	...	....	....	...

O. Vogel * discusses the magnetisability of natural and prepared nickel iron. Hopkinson's investigations showed that nickel iron alloys, in particular a nickel steel with 25 per cent. of nickel, occur between temperatures of from a few degrees below 0° C. to + 580° C. in two conditions, in one of which the metal can be magnetised, while in the other this is not possible. By cooling to the first mentioned temperature it passes from the unmagnetic to the magnetic form, while on again heating it once more becomes non-magnetic. Meteoric irons examined by Leich gave different results. Some could be made strongly magnetic, others less so, and some not at all. Those which became strongly magnetic lost this property, like iron and nickel, when heated and then slowly cooled. This led Cohen to assume that a meteoric iron which behaves like a malleable iron must have been strongly heated. He found meteoric iron to be non-magnetisable, and on repeating Hopkinson's experiments the magnetic strength was found to diminish

* *Zeitschrift für Elektrochemie*, vol. ii. p. 396.

with increasing percentage of nickel, but neither heating strongly nor
cooling to a low temperature gave results such as those Hopkinson
obtained.   This difference in the results is to form the subject of
further experiments.

In the fourth report of the committee on alloys, M. Rudeloff* gives
the results of an investigation of nickel iron alloys, describing the
methods of preparing the test-pieces, and giving the results of analyses
and tensile tests.

Compressed Gas Cylinders.—A report of a committee has re-
cently appeared dealing with the causes of the explosion and the pre-
cautions required to ensure the safety of cylinders of compressed gas.
In appendices are given the results of numerous tests of these cylinders
under a falling weight, and otherwise, when charged or uncharged
with gas, and a number of recommendations are made.   For lap-
welded wrought iron the greatest working pressure is 1800 lbs. per
square inch, and the stress due to this is not to exceed $6\frac{1}{2}$ tons per
square inch.   After annealing, the proof pressure in the hydraulic test
is 3360 lbs., and the permanent stretch must not exceed 10 per cent.
of the elastic stretch.   For lap-welded or seamless steel the working
pressure is 1800 lbs., and the stress $7\frac{1}{2}$ tons in the former and 8 tons
in seamless cylinders.   The carbon is not to exceed 0·25 per cent., nor
the iron to be less than 99 per cent.   Tenacity of the steel is to lie
between 26 and 33 tons per square inch, and elongation is not to be less
than 1·2 inch in 8 inches on a test-bar cut from the finished annealed
cylinder.   Proof pressure and stretch is the same as with iron cylinders.
One cylinder in fifty is to stand crushing nearly flat between rounded
knife edges without cracking.   Various other regulations are sug-
gested for the use of the cylinders, and government inspection is
advised.†

At the Royal Society's conversazione on May 6, 1896, there were
exhibited by the Gas Cylinder Committee, lately nominated at the
request of the Home Office, the results of experiments on steel gas
cylinders.   These showed (1) the danger of using hard or unannealed
steel for gas cylinders ; (2) the extraordinary amount of violent ill-
treatment to which a good soft annealed cylinder may be subjected
without destruction, even when charged to 120 atmospheres ; (3) the

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* *Verhandlungen des Vereines zür Beförderung des Gewerbfleisses*, 1896, p. 65, with
three plates and ten illustrations.

† *Blue Book*, 1896.   1s. 4½d.

effect of very great internal pressure steadily applied, in this case due to the expansion of liquefied ammonia gas which completely filled the cylinder when cold; (4) the violently destructive character of the explosion of mixed gases under pressure, which no practicable cylinder can withstand.

C. Bach * discusses in detail the causes of the explosion of carbonic acid receivers.

Armour-Plate Tests.—In some recent specifications for armour plates in the United States, several changes are made, especially in the treatment.† No mention of the Harvey process is made, but the specifications provide that those plates designated to be face hardened are to be super-carburised previous to finish forging, after which they are to be reduced to their final thickness by forging or rolling at as low a heat as practicable. Finally, after machining and shaping the plate in such a manner as to secure the closest approximation to the desired shape, it is to be hardened. The ballistic requirements of plates will be unusually severe. Plates up to and including those tested by the 6-inch gun will be tested without bolting and backing, but rigidly supported. Plates tested by guns above 6 inches in calibre will be bolted to a backing of not more than 12 inches of oak and two ⅝-inch ship plates. For plates tapering in thickness one of the proposed points of impact may be on the thinner part. When the width of a plate of even thickness is less than 7 calibres of the attacking gun, cracks which extend across the narrow width of the plate shall be waived. The guns to be used for acceptance tests are to be of these calibres:— For plates of less than 4 inches in thickness, 4-inch gun ; less than 5½ inches thick, 5-inch gun ; less than 8 inches thick, 6-inch gun ; less than 11 inches thick, 8-inch gun; less than 14 inches thick, 10-inch gun; less than 16 inches thick, 12-inch gun ; less than 18 inches thick, 13-inch gun. The shells to be employed are those now in service, and the velocities are practically the same as those now employed.

A. W. Stahl ‡ describes the test on September 4, 1895, of an armour plate supported on backing built to represent a section of the framing of the armoured ship *Iowa*, a battle-ship of 11,296 tons, building in the United States. The framing was the size of the plate, 16 feet long

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* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xl. pp. 346–350.

† *United States Army and Navy Journal*, December 1895.

‡ Paper read before the Society of Naval Architects and Marine Engineers, New York, November 1895.

and 7½ feet high, and it was 6½ feet deep.   Full descriptions and illus-
trations are given of the framing.   Four shots were fired, as follows :—

No.	Projectile.		Striking Velocity. Feet per Second.	Striking Energy.		Penetration. Inches.
	Diameter in Inches.	Weight. Lbs.		Total Foot Tons.	Per Ton of Armour. Foot Tons.	
1	10	500	1,482	7,622	286	3·75
2	10	500	1,856	11,954	448·6	11
3	12	850	1,800	19,114	717·23	...
4	13	1,100	1,800	24,763	1,903	...

The third shot cracked the plate and went nearly through it, whilst
the fourth shot struck the detached portion, on the weight of which
the striking energy per ton is calculated above. This projectile went
right through the plate. The framing as a whole was bulged-in two
inches from the line connecting the ends. The fourth shot of course
carried away the framing, but the damage was entirely local, showing
its satisfactory design.

These tests are also described by Captain Jaques,[*] and it is held
that they justify the conclusion that the forging after carburisation,
as practised by the Carnegie Company, benefits very materially the
body of the plate, while at the same time it does not appear to impair
the efficiency of the carbonised surface.

J. Castner [†] describes tests of Krupp armour plates in October
1895, and other tests made with the *Iowa* plate in September 1895 at
Indian Head. The satisfactory results which were obtained in the
United States by rolling an armour plate down to a lesser thickness
after the carburisation, but before the hardening, have led to this pro-
cess being adopted in the manufacture of all the Harveyed plates for
American battle-ships. It is thought that armour plate made in this
way shows greater .resistance to penetration, and is generally better
than plate made in the ordinary way. Such plate, made for the new
battle-ship *Iowa*, when tested gave results which the author shows by
means of photographs. He compares them with similar results ob-
tained shortly afterwards in tests of Krupp steel plates, and considers
that the latter showed themselves to be much the better. He gives
the results of the different tests.

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[*] *Journal of the Royal United Service Institution*, vol. xl. pp. 105–117.
[†] *Stahl und Eisen*, vol. xvi. pp. 273–279, with eight illustrations.

A plate representing 415 tons of 8-inch turret and barbette armour, for the battle-ship *Iowa* and the armoured cruiser *Brooklyn*, was tested at the Indian Head proving grounds on January 8, with results unsatisfactory to the manufacturers, the Carnegie Steel Company. Two ports were cut in the plate to make it represent as nearly as possible the port-plate of a turret. A 6-inch armour-piercing projectile of the Wheeler type, weighing 100 lbs., was fired at the plate with a velocity of 1700 feet a second. The plate broke into three pieces. A second shot was fired at one of the pieces, which also failed to meet requirements.*

A soft-steel-capped projectile, made by the Johnson Company, of Spuyten Duyil, New York, was successfully tested at Indian Head on February 25. The remarkable feature of the test is that while the target was a Harveyised armour plate 7 inches thick, the shell, fired from a 6-inch gun, was made of cast iron chilled by a special process. On the tip of this shell was a soft-steel cap or point, no detail of which could be secured. Of the three shells fired, two fulfilled all the requirements of the test; but the third went completely through the 7-inch armour plate and the heavy backing, and then 14 feet into a dirt-bank behind the target.†

Some illustrations of hardened nickel steel armour Krupp plates tested at Meppen have been reproduced,‡ and further comments are made upon them. These trials have already been referred to.§

Of special interest in connection with the subject of armour is a work, in two volumes, by H. W. Wilson on "Ironclads in Action."‖ This gives a sketch of naval warfare from 1855 to 1895, and includes a short account of the development of the battle-ship in England. All the naval battles and the engagements between forts and armoured ships that have occurred are described.

An illustrated account has been published ¶ of a trial of a Bethlehem plate, which took place on November 23 and December 5, 1895.

Ten photographs have been published ** of results obtained by Krupp's armour within the year 1895.

* *The Engineer*, vol. lxxxi., No. 2092, p. 111.
† *Engineering News*, vol. xxxv. p. 145.
‡ *Iron Age*, vol. lvii. pp. 469–471.
§ *Journal of the Iron and Steel Institute*, 1895, No. II. p. 577.
‖ "Ironclads in Action," by H. W. Wilson, 2 vols. Sampson Low, Marston & Co., 1896.
¶ *Engineer*, vol. lxxxi. pp. 32–33.
** *Ibid.*, pp. 112–113.

Photographs have also been published [*] of Carnegie's double-forged nickel steel face-hardened armour tested at Ochta, near St. Petersburg, at the end of 1895.

H. N. Lemp [†] describes the local annealing of hard-faced armour plates by a modification of the Thomson electric welding process.

- The formula for calculating the perforation of armour suggested by Captain Tresidder is discussed [‡] and compared with those previously proposed by Maitland, Fairbairn, and Krupp.

The advantages of the Wheeler-Stirling projectiles are urged in an article in the *Engineer*,[§] and the author expresses the opinion that they have at the present moment the best record to show of any.

[*] *Transactions of the American Institute of Electrical Engineers; Engineer*, vol. lxxxi. p. 355.

[†] *Ibid.*, p. 429.　　　　[‡] *Ibid.*, p. 487.　　　　[§] *Ibid.*, p. 215.

CHEMICAL PROPERTIES.

Gaseous Compounds with Iron.—H. Morton * recalls a curious circumstance bearing on the question of the power of carbon monoxide to enter into a gaseous combination with iron. When water-gas first came into use in America for illuminating purposes, it was found that it gave rise to mushroom-shaped deposits on burner tips. These deflected the flame and diminished its luminous intensity. Some examples were sent for analysis, and were pronounced to be oxide of iron. Further investigation showed that the deposits were only formed when oxide of iron was used in the purifiers, and then only when there was some reduced or metallic iron present. By taking care that the iron was fully oxidised before use, the difficulty was entirely avoided.

Liquation in Hardened Steel.—A. Ledebur † observes that in attempts to scratch, with a suitable instrument, the polished surface of a piece of steel containing from 0·70 to 1·30 per cent. of carbon, no effect is observed, but when the percentage of carbon exceeds 1·30 a scratch is occasionally noticed, as has been shown by F. Osmond,‡ whose paper it is that Ledebur discusses. If the scratch so produced is closely examined, it will be found that the line is of a very interrupted character ; that is to say, there are at least two constituents in the metal, one harder than the other, and side by side. The one will scratch glass and felspar, the other can be scratched by apatite, and possibly by fluorspar. On a well-polished surface the two constituents can be detected by their slightly different colours, the harder having a tinge of grey, while the softer is silvery white. On treating the specimen with tincture of iodine or dilute nitric acid, polyhedra may be observed, with occa-

* *The Stevens Indicator* (January 1896) ; *Engineering*, vol. lxi. p. 225.
† *Stahl und Eisen*, vol. xvi. pp. 116–117.
‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxxi. pp. 684–685.

sionally traces of the carbide Fe_3C in between them.   Under the treatment the two constituents assume different colorations, and can readily be distinguished from each other.   If the action is continued too long, the surface becomes black from separated carbon.   The harder of the two constituents is the one of which hardened steel, containing over 1 per cent. of carbon, almost exclusively consists. The percentage contents of the softer substance increases with the percentage of carbon until the latter approaches 1·60.   If this percentage is exceeded, then the carbide Fe_3C appears to separate out in quantities, increasing gradually as the percentage of carbon rises. Osmond observes that it is a fairly pure steel, with about 1·57 per cent. of carbon, which shows this action best, and it is found that the steel must be heated to at least 1000° if the highest percentage of this softer constituent is to be obtained, but a temperature exceeding 1100° is not necessary.   It is then necessary to harden the steel as rapidly as possible in ice-cold water, or in very cold mercury.   If this is not done properly, the carbide Fe_3C forms in the hardening of the metal, thus reducing the percentage of carbon in the main mass. With careful manipulation it is possible to obtain about equal quantities of the hard and the soft constituents.   Such an admixture is but very slightly magnetic, as Osmond shows by experimental results.   He considers that the softer substance is non-magnetic.   A steel of this composition cannot be filed, and breaks without bending, partly on account of the brittleness of the harder constituent, and partly on account of the slight cohesion between the several polyhedra.   The properties of the softer constituent appear to resemble those of a nickel steel, with about 25 per cent. of nickel, or of a manganese steel, with from 12 to 13 per cent. of manganese, steels, that is, which on slow cooling do not show any of the critical points.

Discussing these experiments of Osmond, Ledebur observes that they are in accord with the long-known fact that the higher the percentage of carbon is in a steel, the less strongly can it be heated without fear of endangering its good qualities.   That the change in the character of the metal takes place while it is being heated, and not while it is being hardened, the author considers absolutely certain, and consequently 1000° of temperature have a greater effect than heating to 800° has.   With these observations of Osmond, Reiser's statement stands in complete agreement, that hard steel cannot be heated above a dull cherry red without becoming brittle.   The author also briefly discusses several other points in Osmond's paper.

Ferro-chromium.—H. von Jüptner* points out that H. Behrens and A. R. von Linge have recently found that on dissolving a 50 per cent. ferro-chromium alloy in concentrated hydrochloric acid, acicular crystals are left undissolved, and that these contain :—

Carbon.	Iron.	Chromium.
10·40	24·60	65·00

They consequently agree approximately with the formula Cr_2FeC_2.

The author has dissolved a ferro-chrome containing 48·06 per cent. of chromium in hydrochloric acid. The residue amounted to 24·07 per cent., and in addition to 2·90 per cent. of silicon this contained :—

Carbon.	Iron.	Chromium.
11·05	23·81	65·14

corresponding approximately to the formula Cr_2FeC_2.

Silicides of Iron and of Chromium.—H. Moissan † has prepared in the electrical furnace iron silicides by direct combination. In other ways the compounds SiFe and $SiFe_2$ had already been prepared. A number of experiments are described, and chromium silicide was found to be so extremely hard that it would scratch both quartz and corundum. Silver appears to dissolve silicon, but not to enter into definite combination with it. The chromium silicide has the formula $SiCr_2$ given to it. With reference to its extreme hardness, above referred to, it is pointed out that most silicides are much harder than the corresponding carbides, and in part also than carbon silicide. Chromium silicide and iron silicide closely resemble each other in their general properties.

The Influence of Carbon on Iron.—In a paper read before the Institution of Civil Engineers, J. O. Arnold ‡ gave the results of researches undertaken primarily to determine whether, at high temperatures, the carbon still remained in combination with the iron. A series of 3-inch square crucible steel ingots, ranging in carbon between 0·08 per cent. and 1·47 per cent., the total impurities other than carbon averaging 0·2 per cent., were hammered and rolled to $1\frac{1}{16}$ inch diameter. They were then submitted to chemical, mechanical, microscopical, thermal, and magnetic tests, in three standard

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 14.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxxi. pp. 621–626.

‡ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxiii. pp. 127–162.

physical conditions—namely normal, or cooled in air; annealed, or very slowly cooled; and hardened, or very rapidly cooled. The differential analyses for carbon confirmed the conclusion arrived at by the author in a previous research, that the hard plates of Sorby's laminæ consisted of pure crystallised Fe_3C; and under certain conditions contained practically the whole of the carbon present in the steel. The mechanical tests showed that in normal steels the tenacity increased with the carbon up to 1·2 per cent.; a further addition of carbon causing a diminution in the stress. Thus, the tenacity of ingot iron containing about 0·1 per cent. of carbon was found to approximate to 21 tons per square inch; the maximum stress sustained by iron containing 1·2 per cent. being nearly 62 tons per square inch, whilst the stress registered at 1·5 per cent. fell back to about 56 tons. In the case of thoroughly annealed steels the stresses were distinctly less than those obtained from the corresponding normal metals, the maximum tonnage being registered at about 0·9 per cent. of carbon. With higher carbons the strain rapidly diminished; being at 1·5 per cent. of carbon only about 22 tons. The ductility of normal steel diminished with the carbon; the elongation with 0·1 per cent. of carbon being 47 per cent., and at 1·5 per cent. 3 per cent. on 2 inches. The ductility of the corresponding annealed metals was slightly greater up to 0·65 per cent., but between 0·65 per cent. and 1·2 per cent. it was less than that obtained from the normal steels, registering a minimum at about 0·9 per cent. Under compression the softness of normal steel decreased with the carbon until 0·9 per cent. of that element was present; between 0·9 and 1·5 per cent. the flow was practically stationary. Annealed steels under compression indicated a maximum hardness at 0·9 per cent., and were distinctly softer than the normal metals. Between 0·9 per cent. and 1·5 per cent. the steel became remarkably soft under compression; steel with 1·5 per cent. of carbon was softer than iron containing 0·1 per cent. In hardened steels the rigidity of the metals increased enormously as the carbon rose, and between 0·9 per cent. and 1·5 per cent. the metal was practically incapable of flow under compression. The remarkable mechanical tests obtained from the annealed steels between 0·9 per cent. and 1·5 per cent. were undoubtedly due to the decomposition of Fe_3C into free iron and graphite. The microscopical investigation showed that pure iron consisted of cubic and octahedral crystals. On the introduction of carbon a new constituent, which became dark brown on etching, appeared and remained sharply localised in the iron, until at about 0·9 per cent. the

whole mass consisted of this constituent. This point was defined as the saturation point of steel. Steels containing less than 0·9 per cent. of carbon and consequently free iron, were termed unsaturated; whilst steels containing above 0·9 per cent. were distinguished as supersaturated, because they contained an excess of Fe_3C. The particular method necessary to obtain reliable sections of hardened steel was described. The general results of the microscopical examination sustained the theory that the hardness of quenched steel was due not to a hard allotropic modification of iron, but to a definite sub-carbide corresponding to the formula $Fe_{24}C$. This formula involved a maximum evolution of heat of combination, and a maximum absorption of heat of dissociation respectively, on cooling and heating, in iron containing about 0·9 per cent. of carbon. Determinations of these heats *in vacuo* gave decisive maxima both on heating and cooling at 0·89 per cent. of carbon. The magnetic observations on hardened steels had led the author to the conclusions that (1) the magnetic permeability varied inversely as the carbon present; (2) the permanent magnetism was directly proportional to the carbides of iron present; and (3) in iron containing between 0·1 per cent. and 0·9 per cent. of carbon, the permanent magnetism was directly proportional to the sub-carbide of iron present. The author based the existence of a sub-carbide of iron possessing the formula $Fe_{24}C$, to which the phenomena of hardening and tempering were due, on the following experimental facts: (1) the well-marked saturation points in the micro-structure of normal, annealed, and hardened steels; (2) a sharp maximum in a curve, the co-ordinates of which were heat evolved or absorbed at the carbon change point, Ar_1, and the carbon percentage; (3) a point in the compression curve of hardened steels at which molecular flow ceased; and (4) a sharp maximum in a curve, the co-ordinates of which were the carbon percentage and permanent magnetism in hardened steels.

A lengthy discussion followed the reading of the paper,[*] in which T. Andrews, J. E. Stead, W. C. Roberts-Austen, R. A. Hadfield, J. Head, W. Anderson, and A. B. W. Kennedy took part. The correspondence on the paper includes contributions from H. Behrens, H. Le Chatelier, H. D. Hibbard, J. Hopkinson, H. M. Howe, H. C. Jenkins, P. Kreuzpointner, A. M'William, W. Metcalf, F. C. J. Müller, F. Osmond, W. Ripper, C. P. Sandberg, A. Sauveur, R. G. Scott, A. Vosmær, R. Wallis-Jones, and B. W. Winder.[†]

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[*] *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxi. pp. 181-215.
[†] *Ibid.*, pp. 215-259.

Weeren * summarises the recent investigations of the chemical properties of iron, reference being made to the influence on iron of carbon, silicon, boron, aluminium, and arsenic.

Formation of Nickel Carbonyl.—Sodium decomposes ethylic oxalate into ethylic carbonate and carbonic oxide. According to H. Frey,† when ethylic oxalate is added to finely divided nickel chloride and sodium, suspended in light petroleum, traces of nickel carbonyl are found in the gas which is evolved. Ferric chloride, when treated in the same way, gave no trace of iron carbonyl.

Reduction of Iron Oxides by Carbonic Oxide.—According to I. Braithwaite,‡ at a low red heat carbonic oxide is found to be oxidised more readily by ferric oxide than by magnetic oxide, whilst ferrous oxide is still less active. Conversely, carbonic anhydride is reduced more quickly by iron than by ferrous oxide, and not at all by magnetic oxide.

Gallium and Indium in Steel.—At the Royal Society's conversazione on May 6, 1896, there was exhibited by W. N. Hartley a series of photographed spectra illustrating an investigation of the Bessemer Flame, as seen at the North-Eastern Steel Co.'s Works at Middlesbrough-on-Tees, in which the presence of the rare element gallium was recognised by a single line in its spectrum, and separated from both the metal and the ore of the district. The series showed :—Four photographs of the Bessemer flame seen issuing from the converters, 15 inches by 12 inches ; two plates of spectra of the Bessemer flame, 12 inches by 10 inches ; thirteen spectra taken at intervals during the blow, and also during the overblow. The spectra slightly overlap. This series shows the increase of temperature during the combustion of the carbon. A gallium line is seen in ten of the spectra. Three plates of spectra were also shown, illustrating the method of detecting gallium by spectrum analysis of substances separated from the metal and ore. Another plate showed : (1.) Spectrum of sesquioxide metals separated from 1 kilogramme of Cleveland iron ore. (2.) The spectrum of an insoluble residue collected on a filter-paper and burnt. (3.) Precipitate from the solution of a manganese ore collected on a filter and burnt. It contained indium.

* *Dingler's Polytechnisches Journal*, vol. ccxcix. pp. 9, 34.
† *Berichte der deutschen chemischen Gesellschaft*, vol. xxviii. pp. 2512-2514.
‡ *Chemical News*, vol. lxxii. p. 211.

Prevention against Rust.—Spennrath [*] has shown that iron only rusts when the oxygen of the air acts on it in conjunction with moisture. In dry air no rust will form. He mentions the various means in use for protecting iron from rust. These include oil paints of various kinds, and numerous others to which he refers, discussing their action at some length, and giving the results of a number of experiments.

Action of Oils on Cast Iron.—D. Holde [*] publishes the results of tests of lubricating oils made at the Royal Testing Institute at Berlin. He tabulates the relative action of various kinds of oil on cast iron, each oil acting on the iron under the joint action of superheated steam of 10 atmospheres tension. Scotch thin-fluid mineral oil showed the least action, and almost of equal value was a thick-fluid opaque brown-black mineral oil. These caused a slight diminution in weight of the iron, but some others of the samples attacked the metal very considerably. Thus, while the two oils above referred to only caused a loss in weight of 4 milligrammes after six hours' action, one sample of refined rape oil caused a loss of 205 milligrammes, another similar sample a loss of 118 milligrammes, and tallow a loss of 168 milligrammes.

* *Stahl und Eisen*, vol. xvi. pp. 221-22.
† *Mittheilungen aus den königlichen technischen Versuchsanstalten*, vol. xiii. pp. 174-196.

CHEMICAL ANALYSIS.

CONTENTS.

I.—ANALYSIS OF IRON AND STEEL.

The Analysis of Iron.—A. Carnot * describes the methods in general use at the present time for analysing pig iron, malleable iron, and steel. He describes the method of taking a sample for analysis, the determination of carbon, silicon, phosphorus, arsenic, copper, sulphur, manganese, chromium, nickel, tungsten, molybdenum, titanium, vanadium, aluminium, and iron, and the analysis of slags.

A circular has been issued by the chemical section of the Engineers' Society of Western Pennsylvania, asking for the co-operation of chemists in an effort to collect for publication the methods in general use for the analysis of iron ores, pig iron, and steel. The particulars asked for include descriptions of the methods used for the determination of silica, iron, phosphorus, and manganese in ores; of silicon, sulphur, phosphorus, and manganese in pig iron; of carbon (by combustion), sulphur, phosphorus, manganese, and nickel in steel. In response, several valuable communications have been received, namely:—

J. S. Unger † describes the methods for the analysis of ores, pig iron, and steel in use in the laboratory of the Carnegie Steel Company at Homestead, Pennsylvania; F. Crabtree ‡ describes those in

* _Annales des Mines_, vol. viii. pp. 357–478, 481–543.
† _Proceedings of the Engineers' Society of Western Pennsylvania_, vol. xii. ; Supplement, pp. 1–14.
‡ _Ibid._, pp. 17–20.

use at the laboratory of the Monongahela Furnace, M'Keèsport, Pennsylvania; J. M. Wilson * those in use in the laboratory of the Junction Iron and Steel Company, Steubenville, Ohio; R. Miller † those in use in the laboratory of the Carnegie Steel Company, Lucy Furnace, Pittsburgh, Pennsylvania; E. S. Johnson ‡ those used in the laboratory of the Black Diamond Steelworks, Pittsburgh; S. M. Rodgers § those in use in the laboratory of the Hainsworth Steel Company, Pittsburgh; R. G. Johnston ‖ those in use in the laboratory of the Hainsworth Steel Company, Edith Furnace Department, Allegheny; and C. B. Murray ¶ those in use in the laboratory of the Carnegie Steel Company, Edgar Thomson Steelworks and Furnaces, Braddock.

J. M. Camp ** describes at length the analytical methods in use at Duquesne. Particulars are given for the determination of phosphorus in pig iron and steel, and also in ores; of iron and manganese in ores; of manganese in steel and pig iron; of silicon in pig iron; of nickel in steel; of manganese by colour; of sulphur in pig iron and steel, both by the aqua regia and by the iodine methods; and of carbon by combustion in steel.

Determination of Carbon.—L. Schneider †† observes with reference to his method for the determination of carbon in iron by combustion with copper and lead in a stream of oxygen, that while the preparation of pure powdered lead is easy enough, that of pure copper powder is much more difficult. At first he prepared this by first oxidising copper wire, and then reducing this again in a current of hydrogen, but now he employs instead a powdered phospho-copper. This is sold commercially with 15 per cent. of phosphorus, and may be readily broken down and powdered. It burns in oxygen more readily than copper, but the commercial article contains a little iron with carbon in it. It may be purified by treatment for twenty-four hours with concentrated hydrochloric acid. The combustion is subsequently effected by mixing 3 grammes of the powdered iron sample with 10 grammes of a mixture of lead and phospho-copper, burning in a current of oxygen, and determining the quantity of carbonic anhydride produced.

* *Proceedings of the Engineers' Society of Western Pensylvania*, vol. xii. pp. 21-28.   † *Ibid.*, pp. 29-30.
‡ *Ibid.*, pp. 31-45.   § *Ibid.*, pp. 31-45.
‖ *Ibid.*, pp. 55-58.   ¶ *Ibid.*, pp. 59-66.
** *Iron Age*, vol. lvi. pp. 900-901, 1100-1101.
†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. p. 121.

Determination of Silicon.—According to Liebrich,* to determine silicon in pig iron rapidly the following method ·is applicable. After dissolving and evaporating to render the silicon insoluble, the residue is taken up and filtered in the usual way. The filter is then ignited in a platinum crucible, without taking care to wash very thoroughly, and as soon as the ignited filter has "fallen together," a piece of potassium hydrogen sulphate is added, about three grammes for every gramme of iron used in the assay. The whole is then heated, first gently, and subsequently over the blow-pipe. The graphite burns off completely. After the mass in the crucible has cooled, it is dissolved in the hot in about 150 cubic centimetres of water acidified with a little hydrochloric acid. The silica remains undissolved, and is pure white in colour. Iron, and any titanic anhydride that may be present, pass into solution. The potassium hydrogen sulphate is best prepared by pouring 120 grammes of sulphuric acid on to 200 grammes of potassium sulphate placed in a platinum dish, and then heating until the sulphuric acid begins to fume away. After cooling, the solidified mass is broken up.

Determination of Phosphorus.—A. A. Blair † discusses the methods for determining the percentage of phosphorus in two samples of steel as described by G. E. Thackray, ‡ and re-calculates some of the results, using different factors for the reduction of molybdic acid, and for the amount of phosphorus in the ammonium phospho-molybdate. He summarises the twenty-seven methods described, as falling under two heads, the acetate method (A) and the molybdate method. The latter is further subdivided into five distinct methods :—

1. Titrating the reduced molybdic acid after passing the solution through the reductor (B).

2. Titrating the reduced molybdic acid after boiling with metallic zinc and filtering (C).

3. Weighing the precipitated ammonium phospho-molybdate (D).

4. Re-dissolving the precipitated ammonium phospho-molybdate in ammonia, and precipitating the phosphoric acid as ammonium magnesium phosphate, with final weighing as magnesium pyrophosphate (E).

* *Stahl und Eisen*, vol. xv. p. 1058.

† *Transactions of the American Institute of Mining Engineers*, Atlanta meeting (advance proof).

‡ *Journal of the Iron and Steel Institute*, 1895, No. II. p. 590.

5. Determining the amount of ammonium phospho-molybdate by ascertaining the quantity of standard alkali required to neutralise it (F).

An analysis of the results obtained by the different methods is given in the annexed table. No. 1 is sample 19,915; No. 2 is sample 19,533.

	Method A.		Method B.		Method C.	
	Sample No. 1.	Sample No. 2.	Sample No 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.
Number of results .	3	3	3	3	2	2
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Highest . . .	0·049	0·081	0·0515	0·0835	0·049	0·083
Lowest . . .	0·046	0·078	0·0495	0·0816	0·045	0·080
Average . . .	0·048	0·080	0·0500	0·0830	0·047	0·082

	Method D.		Method E.		Method F.	
	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.
Number of results .	6	6	11	11	4	4
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Highest . . .	0·052	0·086	0·055	0·089	0·053	0·086
Lowest . . .	0·049	0·083	0·046	0·076	0·046	0·078
Average . . .	0·050	0·084	0·049	0·083	0·049	0·081

It is much more satisfactory to have results obtained by different methods confirm each other than to have a number of agreeing results by the same method; therefore, the close agreement between the results obtained by the acetate method and those obtained by the molybdate method is gratifying. The average by the acetate method is 0·049 and 0·081, excluding some low results. The average of all the averages is 0·049 and 0·083. On the whole these results show a decided advance in accuracy over any previous series, and give strong hope that the adoption of a single method will eliminate all errors except those due to carelessness.

H. Neubauer * adopts the following method in the determination of phosphorus by the molybdate method. The yellow precipitate is dissolved in 100 cubic centimetres of 2·5 per cent. ammonia solution. The precipitation is effected by means of the usual magnesia mixture: 55 grammes of crystallised magnesium chloride and 70 grammes of

* *Zeitschrift für Angewandte Chemie*, 1895, p. 575.

ammonium chloride dissolved in two litres of water containing 2·5 per cent. of ammonia. The addition of the magnesia mixture should be effected slowly, stirring the solution. This should take at least a minute to effect.

In the subsequent treatment the author recommends providing the lid of the crucible with a thin coating of magnesia, in order to enable it to retain any phosphoric acid that may have sublimed.

The filter containing the magnesia precipitate is ignited direct at as low a temperature as possible. On raising the temperature, even though the precipitate is not completely whitened, the cover prepared as above should be put on, because even at a medium red heat some phosphoric anhydride passes off. The heating is to be continued for about an hour over a strong Terquem or Teclu burner, and another half an hour's heating may be necessary to ensure constant weight if the precipitate was large. The whole crucible must be red-hot, and not simply the bottom portion.

The author considers the use of the Gooch crucible to be inadvisable.

Determination of Manganese.—L. Rürüp [*] publishes the results of comparative determinations of manganese in iron and steel. The methods the author examined were those in ordinary use in ironwork laboratories. In addition to the manganese he also determined the other constituents in his steels examined. The analyses gave the following percentage results :—

	C.	Mn.	P.	Si.	S.	Cu.
Crucible steel	0·753	0·33	0·020	0·03	0·03	0·075
	0·747	0·33	0·020	0·03	0·03	0·061
Bessemer steel	0·222	0·62	0·017	0·41	0·06	0·100
	0·217	0·62	0·013	0·42	0·06	0·094
Open-hearth steel	0·292	0·45	0·050	0·09	0·03	0·042
	0·295	0·45	0·059	0·09	0·03	0·047
Basic ingot iron	0·075	0·18	0·090	0·01	0 01	0·071
	0·075	0·18	0·090	0·01	0·01	0·067

The experiments were made under as nearly identical conditions as possible. These the author describes. The methods he examined included both gravimetric and volumetric. The former comprised the determination of the manganese—(1) as sulphide ; (2 and 3) by precipitation

* *Chemiker Zeitung*, vol. xx. pp. 285–286, and 337–338.

with bromine, and weighing as Mn_3O_4; and (4) determination by the Ford method, weighing as Mn_3O_4. The volumetric methods included (a) the Volhard method, (b) determining by precipitating the iron with sodium sulphate and titrating the manganese, and (c) determination by the Hampe chlorate method. The author, in describing the sulphide gravimetric method, observes that to get satisfactory results the following points must be noted: (1) Too much sodium acetate must not be used in precipitating the iron, as the results obtained are otherwise too low; (2) the Mn_3O_4 precipitate, after ignition, must be again washed with hot water, or otherwise the results will be too high; (3) the Mn_3O_4 precipitate must be then again re-dissolved, after ignition, with a little dilute hydrochloric acid, with the addition of sulphurous acid, and the solution neutralised with ammonia, to precipitate any iron that may be present with the manganese, or otherwise results will be obtained which are too high; (4) after the first precipitation and filtration of the manganese, for the sake of certainty the filtrate must be again treated with a little bromine water, to see if any more is precipitated. The Ford method is next described. This is but little used in Germany. Using a larger quantity of potassium chlorate than is suggested by Blair, good results were obtained, but when less chlorate was used the results were too low. This also happened if the solution was not boiled for an adequate length of time. The author then passes to the Volhard method. He describes the method, and found that while the results were in no way interfered with, even if all the hydrochloric acid used in the operation was not evaporated off, yet, on the other hand, the results were always too low if, after the filtration, free zinc oxide remained in the solution. The next method described is that in which the iron is precipitated by sodium sulphate in the cold, and the manganese titrated with permanganate. This method is both simple and accurate, except that care must be taken in the neutralisation. Before the addition of the sodium sulphate the solution must be perfectly neutral, which results as soon as the solution is no longer quite clear, but no definite precipitate has formed. The author dissolved 4 grammes of the filings in 75 cubic centimetres of nitric acid of 1·2 specific gravity, with the addition of 10 cubic centimetres of hydrochloric acid, poured into a litre flask, neutralised exactly with sodium carbonate; added 18 cubic centimetres of sodium sulphate solution (1 to 10), and diluted up to the mark. The whole was then well mixed, the precipitate allowed to settle, and filtered into a three-quarter litre flask, poured again into

an Erlenmeyer flask, 15 grammes zinc sulphate added, and the whole
heated to boiling, followed by titration by permanganate.

The Hampe chlorate method is then described, and the author next
details the results obtained by the different methods. He shows that,
provided the conditions he describes are properly maintained, all the
methods mentioned give results which are fully adequate for works
laboratories.

H. von Jüptner * has already referred to the influence exerted by
the use of different values for the atomic weights on the result of
determinations of manganese. He now deals with this at greater
length, and, referring to the standardising, shows that the use of oxalic
acid gave very satisfactory results. The use of iron without any pre-
vious reduction with zinc gave in most instances results which were too
high, but in some cases the results were lower than when oxalic acid
was used. Standardising with metallic iron, after reduction with zinc,
gave in part the same and in part higher values than without reduc-
tion. In part the results were higher, and in part lower, too, than
when oxalic acid was employed. Whether these differences were due
to variations in the composition of the iron, or to inevitable errors
of observation, is uncertain. The use of the iron-ammonium double
salt in standardising permanganate is only then permissible for
accurate work when its percentage of iron has been determined
gravimetrically and the solution reduced with zinc. Of course it is
necessary to allow the corresponding quantity of $K_2Mn_2O_8$ for the
zinc used.

G. C. Stone † discusses the Volhard method of determining manga-
nese. He has found that, provided all the iron was oxidised, it
made no difference whether nitric, sulphuric, or hydrochloric acid was
used. The only difficulty occurred when the proportion of manganese
was extremely small, in which case it was difficult to get the precipi-
tate to cohere so as to give a clear solution in which to perceive the
end reaction.

Determination of Sulphur.—E. J. Read ‡ illustrates a convenient
apparatus for the determination of sulphur in iron, in which a most
efficient absorption is obtained with the use of only a small quantity
of absorbent.

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliv. pp. 15-20.
† *Journal of the American Chemical Society,* vol. xviii. pp. 228-230.
‡ *Chemical News,* vol. lxxii. p. 299.

F. A. Matthewman [*] has instituted an exhaustive inquiry into the present methods of estimating sulphur in iron and steel.

Determination of Chromium.—In the separation of ·chromium from iron, L. Giacomelli [†] is of opinion that the chromium is best separated by oxidising the ammonia precipitate, containing only the mixed ferric, chromium, and aluminium hydroxides, with a few drops of nitric acid and potassium chlorate. The chromium being thus oxidised to chromic acid, the iron and alumina can be precipitated as hydroxides with ammonia, and separated by means of caustic soda. The chromic acid can be recognised in the filtrate by means of lead acetate after acidification with acetic acid.

Determination of Arsenic.—A. Carnot [‡] considers the question of the determination of small quantities of arsenic. The ordinary methods for this purpose, he observes, leave much to be desired, and he adopts a method in which the arsenic is precipitated as sulphide, and this subsequently converted into arsenic acid by the aid of ammoniacal silver nitrate, and hydrogen peroxide. It is then determined as bismuth arsenate. To do this, the arsenic sulphide is washed, and treated with warm and strongly diluted ammonia. This readily dissolves the sulphide. Enough silver nitrate solution is then added to precipitate the whole of the sulphur as silver sulphide, while the whole of the arsenic remains in solution as ammonium arsenate or arsenite. The solution is then heated for some minutes, and care is taken to make sure that no further precipitation results from the addition of the silver solution. A few drops of pure hydrogen peroxide are then added, and this, in the presence of the excess of ammonia, oxidises any arsenite present to arsenate. The solution is then heated until the whole of the ammonia has been driven off, and slightly acidulated with a few drops of nitric acid. Any silver arsenate or silver chloride, which may have been precipitated when the ammonia was driven off, is in this way redissolved. The solution is then filtered and washed, and then to the filtrate a nitric acid solution of bismuth nitrate is added. This solution must contain at least five or six times as much of the bismuth salt as there is arsenic present. An excess of ammonia is added, and the whole then boiled for a few

[*] *Journal of the West of Scotland Iron and Steel Institute*, vol. iii. pp. 1–76.
[†] *L'Orosi*, vol. xviii. pp. 48–49; *Journal of the Chemical Society*, vol. lxx. p. 128.
[‡] *Comptes Rendus de l'Académie des Sciences*, vol. cxxi. p. 20.

minutes.   After the bismuth hydrate and bismuth arsenate have settled out, the supernatant liquid is decanted through a small weighed filter, and the precipitate itself boiled with water containing one - fifteenth of its volume of nitric acid of 36° B.   The bismuth hydrate passes into solution, while the arsenate remains completely undissolved. This is collected on the weighed filter, washed first with acidulated water, and then with pure water, dried at 110° C., and weighed as $Bi_2O_3As_2O_5 + H_2O$, corresponding to a percentage of arsenic of 21·067.

II.—ANALYSIS OF IRON ORES AND SLAGS.

The Dry Assay of Iron Ores.—F. Büttgenbach [*] again [†] refers to the use of the dry assay as a method of rapidly determining the actual value of an iron ore.   He points out that it is peculiarly adapted in ascertaining the furnace value of iron ores high in manganese.   It is not enough, he observes, to know the exact percentage of manganese in an iron ore to calculate the percentage of that element which will pass into the pig iron made.   It is not merely a question of the percentage of the manganese in the ore, but also of the chemical and physical conditions in which it exists there, and analysis alone does not admit of any accurate deductions as to the composition of the resulting metal.   In some ores all the manganese passes into the pig iron, while in others, and it may be ores even richer in manganese, a not inconsiderable portion of the manganese will pass into the slag, even though this may be highly basic in character.   The value of the dry assay is therefore evident.

In another memoir, F. Büttgenbach [‡] observes that the percentage of manganese which will pass into the pig iron from the ore charge smelted depends on the mode of occurrence of the manganese in the ore.   He ascertains this by the aid of two fusion assays, the one with a very basic and the other with an acid slag.   In the first of these all the manganese that is reducible will pass into the iron button, while in the other all the manganese will pass as manganous silicate into the slag.   The percentage of manganese that has passed into the iron is represented by the difference between the two weights.

[*] Oesterreichische Zeitschrift für Berg- und Hüttenwesen, vol. xliii. p. 597.

[†] Journal of the Iron and Steel Institute, 1895, No. II. p. 599.

[‡] Oesterreichische Zeitschrift für Berg- und Hüttenwesen, vol. xliv. pp. 65–66.

Separation of the Metals of the Iron Group.—C. L. Hare [*]
gives the following method for the qualitative separation of the metals
of the iron group : To a solution of the metals of this group, ammonia
and ammonium chloride are added, and the whole heated and filtered.
The precipitate consisting of the hydrates of iron, aluminium, and
chromium, is boiled with caustic soda and filtered, the filtrate acidulated,
and aluminium separated by the addition of ammonia. The residue,
the hydrates of iron and chromium, is boiled with caustic soda and
a few cubic centimetres of hydrogen peroxide, and filtered.   In the
presence of chromium the filtrate is yellow, and gives with lead acetate
a yellow precipitate of lead chromate.   The iron hydrate is dissolved
in hydrochloric acid, and precipitated with potassium ferrocyanide.
To the filtrate from the iron, aluminium and chromium precipitate,
freshly prepared ammonium sulphide is added, heated and filtered.
The resulting precipitate is treated with dilute cold hydrochloric acid
to dissolve manganese and zinc, the residual cobalt and nickel sulphide
is dissolved in aqua regia, the excess of acid almost completely evapo-
rated off, a slight excess of tartaric acid, and a large excess of
sodium hydrate added. The whole is then heated, and sulphuretted
hydrogen passed through as long as a precipitate results. The pre-
cipitated cobalt sulphide is immediately filtered off.   In the presence
of nickel the filtrate is a deep brown, and in its absence, yellow or
colourless.

Analysis of Basic Slag.—M. Gerlach [†] and M. Passon discuss
the question of the determination of the soluble phosphoric acid in
basic slag.   Two years ago, P. Wagner showed that the relative
manurial value of basic slag was determinable by its behaviour when
treated with an aqueous solution of ammonium citrate containing free
citric acid.   The larger the quantity of phosphoric acid dissolved out
by this re-agent, the more valuable the slag.   The Wagner solution
contains in one litre 60 grammes of crystallised citric acid, and 11·17
grammes of ammonia.   As this quantity of ammonia neutralises 46
grammes of citric acid, there remains 14 grammes of free citric acid
in this solution.   The authors describe comparative tests made with
eighty-four different samples of basic slag, in which the solubility of
the phosphoric acid in the Wagner solution is compared with the
degree of solubility shown when a solution was used which simply

[*] *Journal of the American Chemical Society*, vol. xvii. p. 537.

[†] *Chemiker Zeitung*, vol. xx. pp. 87-88.

contained 14 grammes of citric acid in one litre. Almost identical quantities of phosphoric acid were dissolved by the two solutions. In three instances only were the results very different, and in these the citric acid solution gave the highest results. The authors consider also the action of other solutions, and they arrive at the conclusion that the large quantity of ammonium citrate which is present in the Wagner solution is unnecessary. With regard to the duration of the extraction they found that in half-an-hour almost as much phosphoric acid was dissolved as in an attack of three hours, and further, that the exact speed of rotation in the Wagner dissolving apparatus is a matter of minor importance.

C. Meineke * publishes the results of a critical investigation of the different methods for the determination of phosphoric acid. Referring in the first instance to its determination by ignition of the yellow ammonium phospho-molybdate, the author observes that he showed years ago that by slightly heating this, the yellow salt might be converted without loss into a blue-black substance, to which the author gave the empiric formula, $P_2O_5,Mo_{24}O_{68}$, and which contains 4·018 per cent. of phosphoric acid. This method has been introduced at numerous iron laboratories. The author some time ago tested it again in connection with the analysis of phosphorite, which he had been accustomed to assay by the Wagner magnesium pyrophosphate method. A comparison between the two methods showed that the magnesia one gave much lower results than were obtained by the direct weighing of the phospho-molybdate. From these it followed that if the Wagner method gave accurate results, then this black phospho-molybdate compound should contain only 3·929 per cent. of P_2O_5 instead of the 4·018 per cent. above stated. Many modifications in the methods of determination of phosphoric acid have been introduced within the past ten years. Quite a large number of minor modifications have been adopted. The author describes the method of preparing the molybdenum solution, and of effecting the determination of the phosphoric acid which he employed in his tests, and he gives the results of a large number of comparative tests. From a consideration of these, he concluded that the percentage 4·018, as originally proposed by him, is too high, and from these results, together with those of a large number of others from different series of experiments, he obtained the following average : 3·949 as the percentage of P_2O_5 in the black ignited phospho-molybdate. This agrees extremely closely

* *Chemiker Zeitung*, vol. xx. pp. 108–113.

with the composition, $24MoO_3 + P_2O_5$, which requires 3·944 per cent. of P_2O_5. These experiments also showed that under conditions which are easy of fulfilment, the yellow ammonium phospho-molybdate can be obtained of constant composition.

Proceeding to a consideration of the determination of phosphoric acid as magnesium pyrophosphate, the author instituted an elaborate comparative examination of the different methods. The Wagner method gave satisfactory results, but variations in the method of ignition lead to slightly variable results. As a general rule the loss of phosphoric acid increases with the percentage, and when the ignition is continued until the weight is constant, the losses in weight with different percentages of phosphoric acid are most irregular. These have been plotted by Neubauer, and they show that the quantity of $Mg (NH_4)_4 (PO_4)_2$ which is precipitated in this method is very variable. The Neubauer corrections are not, however, always accurate. The variation in the weight of the phosphate when only slightly heated and after a constant weight has been obtained, must, the author shows, be a measure of the quantity of metaphosphate contained in the slightly heated phosphate, and also of the ratio existing between the quantities of meta- and pyrophosphate, and must enable the exact percentage of phosphoric acid to be determined. This method is shown by the results of numerous tests, of which the following is one : The difference (d) between the weights of the slightly heated phosphate mixture and of that after ignition until constant weight had resulted $= 110·2 - 109·0 = 1·2$ MgP_2O_5. From the decomposition formula 2 $Mg(PO_3)_2 = Mg_2 P_2O_7 + P_2O_5$, 1 part P_2O_5 corresponds to 2·56 parts of $Mg(PO_3)_2$. The slightly heated phosphate was consequently composed of—

$$3·0 \, Mg(PO_3)_2 = 2·3 \, P_2O_5$$
$$+ \, 107·2 \, Mg_2P_2O_7 = 68·5 \, P_2O_5$$
and contained therefore 70·8 P_2O_5.

There was used 70·1 P_2O_5 in the test, and the excess found was thus 0·7. In nearly every case a slight excess was observed, but it is evident that this method admits of more certain results than those obtainable by the Wagner method and Neubauer table of corrections.

The Mærcker magnesium method is also discussed, and the author observes that the presence of free hydrochloric acid and of chlorides— especially ammonium-chloride—is frequently held to prevent the complete precipitation of the ammonium phosphomolybdate. To prove this he made a series of experiments, and his results show that the

assumption above referred to is incorrect, no variation in the results being observed, and the tedious operation of the conversion of the chlorides into nitrates by evaporation with nitric acid, together with the inaccuracies to which this leads, are therefore quite unnecessary.

W. Hoffmeister * extracts 5 grammes of basic slag in the ordinary way with citrate solution, filters, takes an aliquot portion, and evaporates with sulphuric acid in the proportion of about 5 c.c. of the latter to 1 gramme of slag.   The evaporation is stopped when the thick syrupy solution has become of a yellow colour.   The whole of the silica has then separated out, together with a large part of the lime, the former as such and the latter as sulphate.   By means of hot water the thick mass is worked into a measuring flask, and this after cooling is filled up to the mark with water.   An aliquot portion of this, corresponding to about 0·5 gramme of the slag, is charged into a beaker, on the top of which is placed a funnel, and heated with the addition of 10 c.c. of fuming nitric acid, until the evolution of tiny bubbles has ceased.   After washing down the funnel with water, 50 c.c. are added of the ammonium citrate solution customarily employed in phosphoric acid determinations.   The solution is then cooled, 10 c.c. of magnesia mixture added, and enough ammonia added to neutralise any free sulphuric acid and nitric acid which may be present.   To ensure a complete precipitation of the ammonium magnesium phosphate, the solution is allowed to stand for twelve hours, stirring frequently.   This method gives adequately satisfactory results.

A description is published of a rotating apparatus for use in the determination of phosphorus by the molybdate method.   It is made by F. A. Bayes † of Hildesheim, and is more especially intended for the determination in basic slag 'of that portion of the phosphoric acid which is soluble in a citrate solution.   The rotation is effected by the pull of a falling weight connected with a drum and clockwork apparatus, and stops automatically at the end of half-an-hour, a bell sounding to announce the termination of the rotation.

H. Lasne ‡ determines alumina in phosphates in the following manner : After eliminating the silica in the usual way by evaporation with acid, taking up, and filtering, an aliquot portion of the filtrate is taken.   This should correspond to about 1·25 gramme of the phosphate.   Then 5 grammes of caustic soda, free from alumina

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* *Chemiker Zeitung*, vol. xx. p. 305.

† *Ibid.*, vol. xix. p. 2040.

‡ *Bulletin de la Société Chimique*, vol. xv. pp. 146–157.

and silica, are dissolved in 10 c.c. of water in a nickel dish, and to this about 1 gramme of sodium phosphate is added. This solution is then poured in a thin stream into the solution under treatment, stirring with a metal spatula. The whole is then heated for half-an-hour on a sand-bath, shaking at intervals. After cooling, the solution is brought up to 250 c.c. in a measuring-flask, adding it may be another half c.c. to allow for the volume of the precipitate, and shaking well. Two hundred c.c. are then filtered off, this quantity corresponding to 1 gramme of phosphate. Hydrochloric acid is then added until the precipitate which at first forms is redissolved; 25 c.c. of a solution of ammonium chloride containing 125 grammes in the litre are then added, and to the solution ammonia is added until a lasting precipitate results. The whole is then heated nearly to boiling, and dilute ammonia added until the solution only smells slightly of it. After boiling for five minutes it is filtered rapidly, and the precipitate only washed once after draining. The precipitate is dissolved in from 20 to 25 c.c. of hydrochloric acid, and the solution heated to about 100° C. This solution is added to the filtrate previously obtained from the same precipitate, and the solution is then mixed with 3·5 c.c. of a 10 per cent. solution of ammonium phosphate. This latter must contain about 53·4 grammes of phosphoric acid to the litre. The solution is next neutralised with ammonia, the resulting precipitate dissolved carefully in a few drops of dilute hydrochloric acid, 1·5 gramme of ammonium thiosulphate is added in solution, the whole diluted to 250 c.c., boiled for half-an-hour, replacing the evaporated water, four or five drops of a saturated solution of ammonium acetate added, and again boiled for five minutes. The precipitate is then allowed to settle and filtered hot. The precipitate is washed seven or eight times with boiling water, dried, ignited, and the residue of aluminium phosphate is then weighed. By multiplying the weight of the latter by 0·418 the weight of the alumina is obtained that was contained in the sample examined. The quantity here assumed was 1 gramme.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official statistics of H.M. Inspectors of Mines,* the total number of persons employed in and about all the mines of the United Kingdom during the year 1895 was 733,657, of whom 700,284 worked at the 3512 mines under the Coal Mines Act, and 33,373 at the 724 mines under the Metalliferous Mines Act. Compared with 1894, there is a decrease of 4956 persons at mines under the Coal Mines Act, and a decrease of 484 persons at mines under the Metalliferous Mines Act. Of the 700,284 persons working at mines under the Coal Mines Act, 564,638, or about 80 per cent., were employed below ground. Of the 135,646 surface workers, 4837, or about $3\frac{1}{2}$ per cent., were females. At the mines under the Metalliferous Mines Act, 19,660 persons, or about 60 per cent., worked below ground, and of the 13,713 surface workers, 799, or nearly 6 per cent., were females. The total output of minerals at mines under the Coal Mines Act was 201,738,351 tons, of which 189,652,562 were coal, 2,314,983 fireclay, 7,231,835 ironstone, 2,246,865 oil-shale, and 292,106 sundry minerals. Adding 8800 tons from open quarries, the total output of coal was 189,661,362 tons, which exceeds by 1,383,837 tons the highest amount hitherto recorded, namely, that of 1894.

* "Summaries of Statistics relating to the Mines and Quarries in the United Kingdom," London, 1896.

At the mines under the Coal Mines Act there were 868 separate fatal accidents, causing 1042 deaths. Compared with 1894 there is an increase of fifty-five in the number of accidents, and a decrease of eighty-five in the number of deaths. At the mines under the Metalliferous Mines Act there were forty-six fatal accidents which caused fifty-four deaths. Compared with 1894 there is an increase of seven in the number of accidents, and eight in the number of deaths.

Iron Trade Statistics.—The British Iron Trade Association reports the production of pig iron,* wrought iron,† and steel ‡ in the United Kingdom to have been as follows:—Pig iron, 7,895,675 tons, consisting of 3,977,760 tons of forge and foundry pig iron, 3,528,664 tons of hæmatite pig iron, 110,918 tons of spiegeleisen and ferro-manganese, and 278,333 tons of basic pig iron; puddled bar, 1,148,012 tons; finished iron, 1,087,270 tons; Bessemer steel ingots, 1,535,225 tons, of which 1,093,675 tons were acid and 441,550 tons basic; Bessemer steel rails, 604,338 tons; finished Bessemer steel, 1,284,765 tons; open-hearth ingots, 1,724,737 tons, of which 1,564,868 tons were acid and 159,869 tons basic.

The statistics of furnaces show that there were in operation 344 blast-furnaces, 1775 puddling-furnaces, 101 Bessemer converters, of which 78 were acid and 23 basic, and 346 open-hearth furnaces, of which 308 were acid and 38 basic.

Imports and Exports.—According to the Board of Trade returns, § the exports from the United Kingdom during 1894 and 1895 were as follows :—

Description.	1894.	1895.
	Tons.	Tons.
Pig iron	830,985	866,581
Hoops, sheets, and plates	127,195	103,073
Bar, angle, bolt, and rod	129,132	144,043
Railroad iron	425,242	458,031
Wire	34,675	42,256
Tin plates	353,928	365,982
Cast and wrought	265,883	290,041
Old iron	83,256	95,656
Unwrought steel	211,495	210,100
Steel and iron manufactures	18,667	23,703

* *The Iron and Coal Trades Review*, vol. lii. p. 733,
† *Ibid.*, p. 875. ‡ *Ibid.*, p. 843.
§ *Iron Trade Circular* (Rylands), 1896, p. 56.

The imports for the same period were as follows : *—

Description.	1894.	1895.
	Tons.	Tons.
Iron ores	4,414,812	4,450,311
Bar, angle, bolt, and rod	63,247	67,847
Unwrought steel	8,488	10,862
Girders, beams, and pillars	69,420	69,200
Unenumerated	151,653	163,087
	292,808	310,946

The Coal Industry.—E. Gelhorn † discusses the rise and progress of coal-mining in the United Kingdom, the various improvements in appliances which have been discovered there and introduced into practice, including the wire-rope and the safety-lamp, the methods of coal-mining in use, and the geological conditions under which the coal occurs. He estimates the existing coal reserves at about 500 years' value, as compared with twice that period for the coalfields of Germany. He points out that transport facilities are much in favour of the collieries of the United Kingdom when comparison is made with those of Germany. Not only is water transport available to a much greater extent, and good harbours close at hand, but railway facilities are also much greater; and the scarcity of trucks which has made itself severely felt of late on the State Railways of Germany is altogether wanting on the private lines of the United Kingdom.

II.—AUSTRALASIA.

Mineral Statistics of New Zealand.—According to the official returns ‡ the quantity of coal mined in New Zealand in 1894 amounted to 719,546 tons ; the quantity imported from the Australian colonies was 110,882 tons ; and the quantity exported was 79,943 tons.

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* *Iron and Coal Trades Review*, vol. lii. p. 255.

† Paper read at the General Meeting of the *Eisenhütte Oberschlesien*, Nov. 3, 1895; *Stahl und Eisen*, vol. xvi. pp. 1-7.

‡ "Papers and Reports relating to Minerals and Mining," 1895, p. 15.

The output of the different classes of coal was as follows :—

	Tons.
Bituminous coal	418,895
Pitch coal	102,389
Brown coal	170,825
Lignite	27,753

The number of men employed in connection with coal-mining was 1899, the average output per man being 318 tons.

Coal-Mining in Queensland.—According to P. F. Sellheim,[*] coal-mining in Queensland showed no appreciable expansion in 1894. Although there was an increase of about 6000 tons in the output, the lower market rates prevailing had the effect of showing a decrease of nearly £11,000 in the commercial value of the product. There was very little prospecting, though some coal, said to be of good quality, has been discovered about fifteen miles inland from Lloyd's Bay. The coal industry of Queensland is a thoroughly sound one, but its further development is contingent altogether on new outlets for the product. The total quantity of coal raised in 1894 was 270,705 tons.

In a geographical report, R. L. Jack [†] records the results obtained in the search for coal in Queensland.

III.—AUSTRIA-HUNGARY.

Iron Trade Statistics of Austria.—The Austrian official statistics [‡] show the production in 1894 to have included—

	Metric Tons.
Iron ore	1,214,736
Manganese ore	5,056
Coal	9,572,952
Brown coal	17,332,538
Graphite	24,121
Forge pig iron	620,065
Foundry pig iron	122,307

The production of iron ore shows an increase as compared with that of the previous year, amounting to 105,625 tons, or 9·52 per cent.

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* "Annual Report of the Under-Secretary for Mines." Brisbane, 1895.
† *Ibid.*, p. 160.
‡ *Statistiches Jahrbuch des k. k. Ackerbauministeriums für* 1894 ; *Zeitschrift für Berg- und Hüttenwesen,* vol. xliv. pp. 48–50.

There was a diminution of 159,699 tons in the output of coal—1·64 per cent.—but an increase of 516,583 tons in the output of brown coal—3·07 per cent. The production of foundry iron increased by 14,024 tons, and that of forge pig iron by 65,003 tons, or respectively 12·95 and 11·71 per cent.

The total value of the iron ores raised was £2,676,114, an increase of £193,923. Details are given showing the proportions of the total production both of ore and of pig iron belonging to the different divisions of the Empire.

Of manganese ore 5056 tons were raised, 125 workpeople being employed. The ore was raised in Bohemia, Bukowina, and Carniola.†

The brown coal raised in 1894 shows an increase of 516,583 tons, or 3·07 per cent.; the value, however, diminished by 5·17 per cent. The total exports of brown coal amounted to 7,355,567 tons. Of this quantity 25,431 tons were briquettes. Altogether 44,239 miners were employed in the brown coal mines in 1894, and each raised on the average 392 tons.

The quantity of coal raised showed a diminution of 159,699 tons, and there was a diminution in its value to the extent of 367,171 florins; 1,178,747 tons were coked, yielding 733,905 tons of coke. The yield was thus 62·26 per cent. Of coal briquettes 21,888 tons was made, 21,881 tons of coal and 51 tons of pitch being used in its manufacture.

Details are given showing the quantity of by-products obtained at the coke works attached to the Witkowitz Ironworks and elsewhere. The quantity of coal exported amounted to 1,093,932 tons, that of the coke exported being 156,954 tons. The collieries of Austria gave employment, in 1894, to 53,751 workmen, each of whom raised on the average 178 tons of coal. The total value of all the minerals raised in Austria in 1894 was £7,484,700; and of all the metallurgical products obtained, £3,509,836.

Foreign Trade of Austria-Hungary in 1895.—M. Caspaar,* quoting from official statistics, gives details showing the imports and exports of coal, iron, and iron ore, &c., into and from Austria-Hungary in 1895. These figures include the following :—

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliv. pp. 57–59 and 66–69.

† *Ibid.*, vol. xliv. pp. 188–193.

Imports.

	1894.	1895.
	Metric Tons.	Metric Tons.
Brown coal	16,700	16,797
Coal	4,048,267	4,503,003
Coke	437,259	533,402
Iron ore	88,212	117,600
Manganese ore	2,445	2,772
Iron and iron wares	178,566	229,883

Details relating to the imports of the different varieties of manufactured and unmanufactured iron and steel are given at length :—

Exports.

	1894.	1895.
	Metric Tons.	Metric Tons.
Brown coal	6,902,493	7,110,366
Coal	624,670	639,763
Coke	110,559	119,060
Iron ore	144,309	165,402
Manganese ore	2,099	425
Iron and iron wares	43,368	38,667

Mineral Statistics of Hungary.—There were employed in mining and metallurgical operations in Hungary in 1894, 62,583 workpeople, as compared with 57,132 in the previous year.* For every thousand work-people employed, 6·9 slight, 2·7 severe, and 1·7 fatal accidents occurred. Two-thirds of the total number of accidents were due to falls of the hanging wall, or to blasting. The metallurgical works possessed seventy iron blast-furnaces, nineteen other blast-furnaces, 106 coke ovens, twenty-eight reverberatories, and a large number of other kinds. There were produced at the mines and works :—

	1894.	1893.
	Metric Tons.	Metric Tons.
Coal	1,037,322	982,798
Brown coal	3,180,715	2,877,899
Briquettes	30,057	34,189
Coke	10,250	3,188
Foundry pig iron . . .	17,837	·16,001
Forge pig iron . . .	312,148	307,063
Iron ore exported . . .	237,476	314,133

* *Bany-és koh. lapok,* Nos. 23 and 24, 1895; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xliv. pp. 60–62, and 69–71.

There was an increase of 4·6 per cent. in the value of the pig iron produced. The value of the coal raised was 43·6 per cent. of the total value of the whole production.

Feher Mano * gives a summary of the new Hungarian mining law.

Coal in Austria-Hungary.—C. Schwippel † enumerates the locali-ties in Austria, Hungary, Bosnia, and Herzogowina at which coal occurs, and gives details of the output of each district for 1892.

IV.—*BELGIUM.*

Iron Trade Statistics.—In the years 1893, 1894, and 1895, the production of iron and steel in Belgium was as follows :—

	1893.	1894.	1895.
	Metric Tons.	Metric Tons.	Metric Tons.
Foundry pig iron	74,630	80,110	85,450
Forge pig iron	428,480	378,045	329,651
Acid and basic pig iron	242,154	360,442	414,034
Total pig iron	745,264	818,597	829,135
Weld iron :—			
Sheets	113,602	118,596	101,479
Other kinds	371,419	334,694	351,901
Total weld iron.	485,021	453,290	453,380
Steel :—			
Ingots and castings	273,113	405,661	455,550
Sheets, rails, &c.	224,922	341,318	392,332

In 1893 and 1894 the weld iron rails are shown under the heading of "sheets," in 1895 under "other kinds." ‡

The Cost of Raising Coal—According to the report of the chief inspector, De Jaer, § the cost of raising coal in Belgium has been as follows in the years mentioned :—

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* *Revue Universelle des Mines*, vol. xxxii. pp. 288–296.
† *Zeitschrift für praktische Geologie*, 1896, pp. 32–34.
‡ *Moniteur des Intérêts Matériels*, vol. xlvi. p. 412.
§ *Stahl und Eisen*, vol. xv. p. 1118.

	1894.	1893.
	Francs.	Francs.
Wages	5·31	5·27
Other costs	3·53	3·69
Total cost per ton . .	8·84	8·96
Average selling price . .	9·28	9·30
Profit per ton . . .	0·44	0·34

The relatively diminished cost was due to an increased output. Forty-two collieries showed a profit in 1894 of 8,777,100 francs, and twenty-four a loss of 2,134,400 francs, or a net gain for 1894 of 6,642,700 francs, as compared with a gain of 4,731,700 francs in 1893. While there was a distinct sign of improvement in the coal industry, the following table shows how greatly the profit has diminished in recent years :—

Year.	Output.	Value.	Profit.	Per Ton.	
				Value.	Profit.
	Metric Tons.	Francs.	Francs.	Francs.	Francs.
1890 . . .	14,768,520	191,379,830	38,807,800	12·96	2·63
1891 . . .	14,250,340	177,475,810	24,727,340	12·45	1·74
1892 . . .	14,253,760	145,303,100	7,496,150	10·19	0·52
1893 . . .	14,071,430	130,836,000	4,731,700	9·30	0·34
1894 . . .	15,016,050	139,319,600	6,642,700	9·28	0·44

V.—CANADA.

Mineral Statistics.—Preliminary statistics of the mineral production for 1895 in Canada have been given * as follows :—

	Tons.
Iron ore	102,797
Chromite	3,177
Coal	3,512,504
Coke	53,356
Fireclay	1,329
Graphite	220
Limestone for flux	34,579
Manganese ore	125
Moulding sand	6,765
	Dollars.
Natural gas	423,032
	Barrels.
Petroleum	802,573

* *Engineering and Mining Journal,* vol. lxi. p. 254.

VI.—*CHILI.*

Iron Trade Exports and Imports.—M. Busemann [*] states that the exports of iron, iron wares, and machinery from Germany to Chili was as follows :—

Year.	Tons.	Value.
		£
1889	13,990	248,300
1892	20,299	311,900
1894	14,312	223,200

From the United Kingdom the value of the exports to Chili amounted to :—

Year.	Machinery.	Iron and Iron Wares.
	£	£
1890	3,088,000	671,000
1892	166,000	535,000
1894	177,000	436,000

Expressed in values of 1000 pesos, the imports into Chili in 1893 included :—

	Total.	From United Kingdom.	From United States.	From Germany.
Iron in bars and ingots . . .	733	609	5	96
Sheets	191	170	...	23
Galvanised sheets	1047	988	...	27
Rails	556	470	...	86
Steel in bars and slabs . . .	351	320	12	16
Pipes	269	257	3	10
Galvanised pipes	212	157	4	43
Nails	282	109	118	50
Coal	3380	3285	2	94

[*] *Stahl und Eisen*, vol. xvi. pp. 23–25.

Of the 379,000 pesos' value of sewing machinery imported, 262,000 was from Germany ; and in electric-lighting machinery and electro-motors, the imports from Germany were valued at 21,000 pesos, as compared with 9000 from the United Kingdom, and 12,000 from the United States. Of the 26,000 pesos' worth of needles, 22,000 was from Germany. In scarcely any other item mentioned did the imports from Germany equal or exceed those from the United Kingdom. The imports from France are also mentioned, but they are much smaller in quantity.

VII.—*FRANCE.*

Mineral Statistics.—The production* of iron ore was as follows :—

	Production.	Proportion.
	Metric Tons.	Per Cent.
Oolitic iron ore	3,348,000	89
Brown hæmatite	79,000	2
Other hydrated ores . . .	154,000	4
Red hæmatite	130,000	3
Spathic iron ore	61,000	2
Total . .	3,772,000	100

Iron Trade Statistics.—The production of iron and steel† in France during the year 1895 (provisional figures) and 1894 (definite figures) was as follows :—

	1894.	1895.
	Metric Tons.	Metric Tons.
Forge pig iron	1,600,113	1,516.168
Foundry pig iron	469,601	489,721
Total pig iron	2,069,714	2,005,889
Iron rails	684	427
Merchant iron	685,319	654,645
Plates	99,778	88,599
Total wrought iron	785,781	743,671
Steel rails	182,005	160,417
Merchant steel	340,116	386,168
Steel plates	151,564	170,346
Total steel	818,200	818,954
Bessemer ingots	489,157	488,461
Open-hearth ingots	329,043	330,493
Total steel ingots	818,200	818,954

* *Statistique de l'Industrie Minérale*, Paris, 1896; *Comité des Forges*, Bulletin No. 1047.
† *Ibid.*, Bulletin No. 1051.

Imports and Exports.—The following table shows the French iron trade imports and exports (in metric tons) during 1893 and 1894:—

Description.	Imports.		Exports.	
	1894.	**1895.**	**1894.**	**1895.**
	Tons.	Tons.	Tons.	Tons.
Coke	1,529,982	1,412,950	57,031	84,580
Iron ore	1,638,458	1,651,422	247,519	236,923
Pig iron	59,073	36,984	117,993	161,309
Wrought iron and steel . .	21,894	21,771	24,220	27,663

Use of Steel Rails in France.—In 1895 * there was used by the different railway lines of France 85,244 tons of steel rails as compared with 100,609, 129,338, and 163,840 in 1894, 1893, and 1892 respectively. In 1889 and 1890 the quantities were considerably less.

Algerian Iron Ore.—It is stated † that the iron ore raised in Algeria amounted in 1893 to 393,921 metric tons, mostly magnetic ore from the Mokta el Hadid Mines. All the ore is exported, and most of it comes to England.

Iron Trade Imports of Tunis.—The total value of the imports of all kinds into Tunis in 1894 amounted to £1,676,920. Of this quantity the imports of iron and iron wares amounted to £33,568. Iron for construction purposes is mostly derived from Belgium. Machinery was imported to the value of £31,520. Only agricultural machinery is imported, manufactures not existing to any extent.‡

* *La Métallurgie, February* 16, 1896.
† *American Manufacturer,* vol. lviii. p. 335.
‡ *Stahl und Eisen,* vol. xv. p. 975.

VIII.—*GERMANY*.

Mineral Statistics.—The preliminary official statistics of the German Empire, excluding Luxemburg, show the production of the mines and works for the year 1895 to have been as follows :—

	Metric Tons.
Iron ore .	8,436,518
Foundry pig iron .	703,734
Steel-making pig iron .	2,914,310
Forge pig iron	1,099,710
Castings	14,149
Scraps .	4,290
Total pig iron	4,736,193

Production of Pig Iron.—The statistics collected by the *Verein deutscher Eisen- und Stahl-Industrieller* * show the production of pig iron in Germany, including Luxemburg, in 1895 to have been as follows, charcoal iron and scrap not included. The official statistics for 1894 are also shown :—

Pig Iron.	1895.	1894.	Per Cent. of Total.	
			1895.	1894.
	Metric Tons.	Metric Tons.		
Forge and spiegeleisen	1,524,334	1,334,559	26·3	28·9
Acid Bessemer .	444,495	3,160,848	7·7	8·0
Basic Bessemer .	2,898,476		50·1	47·2
Foundry . . .	921,493	874,624	15·9	15·9
Scrap . . .	...	10,007	...	...
Totals . . .	5,788,798	5,380,038	100·0	100·0

The scrap is not taken into consideration in calculating the relative percentage of the total product. The official figures for previous years are also given, and in another table is shown the relative proportions of the total quantities of the different kinds of pig iron which are produced by the various groups of German blast-furnace plants. The north-western group is by far the most important, producing 2,765,427 tons out of the total quantity of 5,788,798 tons.

* 1896, No. 2.

Iron Trade Statistics.—The Imperial Statistical Bureau has published the iron trade statistics of Germany for 1894. It is pointed out,* however, that 106 foundries, 5 ironworks, and 8 steelworks were late in sending in details, and of these only those relating to 65 foundries, 3 ironworks, and 7 steelworks could be officially estimated, the production of 41 foundries, 2 ironworks, and 1 steelworks being estimated from other sources. These are calculated to have produced 17,000 tons of castings, 4100 tons of weld iron, and 400 tons of ingot iron.

The statistics published show the following figures :—

	1892.	1893.	1894.
Active iron ore mines	610	561	537
Iron ore raised, tons	11,539,133	11,457,533	12,392,065
Value per ton of ore, shillings . .	3·58	3·47	3·40
Workmen employed	36,032	34,845	34,912
Coal raised, tons	71,372,193	73,852,330	76,741,127
Value per ton, shillings . . .	7·44	6·80	6·68
Workmen employed	289,415	290,632	299,627
Brown coal raised, tons	21,171,837	21,573,823	22,064,575
Value per ton, shillings	2·77	2·57	2·44
Workmen employed	37,480	36,586	35,620
Charcoal pig iron produced, tons . . .	26,222	23,886	20,376
Coke pig iron, tons	4,911,239	4,962,117	5,359,663
Active works	109	103	102
Tons of ore smelted	12,604,939	12,554,966	13,546,465
Workpeople employed	24,325	24,201	24,110
Furnaces in blast	215	204	208
Total blast-furnaces	266	263	258
Run of furnaces, weeks	10,103	9,747	9,878
Foundry pig iron, tons	712,058	739,737	840,095
Acid and basic Bessemer pig iron, tons . . .	2,689,910	2,831,635	3,160,848
Forge pig iron, tons	1,491,596	1,370,298	1,334,559
Direct castings, tons	34,149	34,697	34,529
Active foundries	1,193	1,221	1,235
Total castings, tons	1,011,380	1,050,281	1,121,190
Pig iron and scrap used, tons . . .	1,172,490	1,234,490	1,367,116
Workpeople employed	61,293	63,552	66,131
Active weld-iron works	246	218	213
Manufactures and semi-manufactures, tons .	1,363,293	1,177,661	1,138,816
Workpeople employed	45,989	40,342	38,851
Active ingot-iron works	122	139	146
Manufactures and semi-manufactures, tons .	2,756,217	3,163,442	3,641,224
Workpeople employed	61,092	65,944	69,372
Total manufactures and castings of all kinds, tons	5,165,039	5,439,480	5,958,156
Value of same	£33,770,882	£33,687,464	£35,005,628

* *Verein deutscher Eisen und Stahlindustrieller*, 1895, No. 20.

The tons mentioned above are metric tons. The total number of workpeople employed in 1894 was 233,376 as compared with 228,884 in 1893, and 228,731 in 1892. The average value of the ton of foundry iron sank from 52·59 shillings in 1892, to 49·43 shillings in 1893, and still further to 47·79 shillings in 1894.

Similarly the ton of steel pig iron diminished from 44·60 shillings in 1892 to 42·05 shillings in 1894, and of forge pig iron from 45·36 shillings to 40·77. The average value, too, of the ton of weld iron, manufactured and semi-manufactured, fell from 123·78 shillings in 1892 to 113·64 in 1894, and of the ton of ingot iron, manufactured and semi-manufactured, from 122·25 shillings in 1892 to 110·90 in 1893, and 106·15 in 1894.

Tables * have been published showing in detail the iron trade exports of Germany to 65 countries in the years 1894 and 1895. These included :—

	1894.	1895.
	Metric Tons.	Metric Tons.
Iron ores	2,558,729	2,480,136
Basic slag	85,630	80,056
Scrap	77,723	84,814
Pig iron	154,647	135,289
Blooms, ingots, &c.	41,992	61,808
Rails	119,410	116,627
Rail fastenings, sleepers, &c.	43,343	45,619
Angle iron	130,458	172,863
Malleable iron, bars	300,559	277,991
Malleable iron, sheets, &c.	90,012	124,015
Total iron and iron wares	1,439,527	1,527,894
Total machinery, implements, and waggons	143,224	158,788

The imports included :—

	1894.	1895.
	Metric Tons.	Metric Tons.
Iron ore	2,093,007	2,017,136
Basic slag	88,443	92,251
Total iron and iron wares	270,315	258,227
Total machinery, implements, and waggons	45,982	48,152

The Iron Ore Requirements of German Blast-Furnaces.—E.
Schrödter,† in considering the requirements of the German blast-

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* *Stahl und Eisen*, vol. xvi. p. 229.

† *Ibid.*, pp. 233–263, with nine tables.

furnaces, publishes a complete list of the furnaces, and gives their approximate daily capacity. He also publishes maps showing the position not only of these blast-furnaces, but also of the German iron ore, coal, and brown coal districts, which also show the outputs and the quantity of coke made. Other maps refer to the United Kingdom and the United States.

Dealing first with Upper Silesia, he shows that despite the position of the blast-furnaces being unsatisfactory their yield has gone on increasing in recent years. They have been drawing more and more on foreign ores for their supplies of late, as the author shows in tabular form. These foreign ores are largely of higher percentage than those mined in Upper Silesia, which according to M. Boecher average on the ore heap 35 per cent. of moisture and only 24 per cent. of iron, while at the same time they require about 35 per cent. of limestone for fluxing purposes. These ores are very soft brown hæmatites. It is thought that these ore deposits will be exhausted in a relatively short period. Turning in the next place to Saxony; while but little is being done in connection with the mining of iron ores there, the author adds that it is possible to look there as a source for a considerable production, if under somewhat disadvantageous conditions. With regard to the neighbouring kingdom of Bavaria, the ore deposits near Amberg and those of the Maxhütte are of importance. The former deposits are of Lower Cretaceous age, and the ores are mainly brown hæmatites in lenticular deposits. The percentage of iron varies from 47 to 54; from 0·7 to 1·2 of manganese; from 0·8 to 1·35 of phosphorus, and 7 to 13 of insoluble residue are also present. The ore deposits of the mines belonging to the Maxhütte in Thüringia are very extensive. The ore found near Kamsdorf occurs in Permian limestone, and contains from 40 to 48 per cent. of iron, mostly as carbonate or brown hæmatite, 3 to 4·5 of manganese, and 0·03 to 0·04 of phosphorus. About 60,000 tons is raised per year. Considerable deposits of phosphoric ore have also been found in Thüringia. In Würtemberg for some time past only one small coke blast-furnace has been in blast regularly, and one small charcoal furnace at intervals. The first of these made in 1894–95, 3681 tons of pig iron from a fine-grained clay ironstone of the brown Jura, yielding 34 per cent. of iron in the furnace. It is made into direct castings. Iron ore mines which sell their ore outside Würtemberg do not exist there. The next group the author deals with consists of the mines of Thüringia, the Harz, Brunswick, and Hanover, though some of the mines of the former

district have already been briefly referred to. In Thüringen not one of the charcoal blast-furnaces which were once numerous there is now in blast, and only one such in the Harz. The author refers to several deposits of ironstone, and observes that in the central Harz chain the deposits at Elbingerode are of the most importance. These are referred to in another abstract in this volume. The Ilsede furnaces derive their ores from mines belonging to the company. These yield about 470,000 tons of brown iron ore a year, and the deposits are of very considerable size. The two more important mines are connected by a small gauge-line with the blast-furnaces, and the cost of raising and transporting the ore is but small. The cost of transport of the fuel used is, however, high; still in 1894 the first cost of the ton of basic Bessemer pig iron amounted to only 27·78s. Other ore deposits in Hanover are also mentioned. The author then proceeds to deal in very considerable detail with the ore deposits in Westphalia and the Ruhr district, in Siegen, in the district of the Dill and the Lahn, in Lorraine and Luxemburg, and in Alsace. Passing from a description of the various iron ore fields, he deals statistically with the production and imports of iron ore in and into Germany, and shows that Spain is still the chief exporting country, Sweden being the second chief exporter. He considers briefly the question of ore supplies from these and other countries. A comparison is then drawn with the iron industries of the United Kingdom and the United States, the subject being dealt with statistically; and the cost of transport is next dealt with at some length, the influence this has on the ore mining districts being considered.

In his concluding remarks the author states that about two-thirds of the iron ore mined in Germany is obtained from the Lorraine-Luxemburg district, while more than half the coal and two-thirds of the coke are obtained from the Ruhr district. There ought, he adds, to be better means of water transport between these two districts. While in Germany the older geological formations, up to and including the Carboniferous, no longer yield the quantities of ore required for the blast-furnaces, a condition which has been already reached in the United Kingdom, prominent geologists consider that in Germany the more recent formations of the Jura and the Chalk give promise of important iron ore deposits. The ores found here frequently, however, cannot compete with the richer foreign ores that are imported. The question of the reduction of freight rates is therefore of the utmost importance to the German iron industry. A lengthened discussion ensued on the reading of this paper.

E. Schrödter * publishes a list of all the German blast-furnace works, showing for each works the statistics mentioned below :—

Provinces.	Blast-Furnaces in Blast.	Blast-Furnaces out of Blast.	Blast-Furnaces Building.
Upper Silesia—			
10 works	27	7	2
Würtemberg—			
1 works	1	...	...
Bavaria—			
2 works	3	1	...
Thüringia, Harz, Brunswick, Hanover—			
8 works	8	10	...
Westphalia, Lower Rhine—			
22 works	50	11	4
Middle Rhine—			
7 works	9	4	...
Dill-Lahn (Nassau)—			
4 works	6	1	...
Siegen—			
24 works	28	5	...
Saar—			
4 works	18	1	1
Lorraine—			
9 works	27	3	2
Luxemburg—			
7 works	24	...	...

The approximate furnace yields are also given.

Iron Trade Statistics of Luxemburg.—According to the official statistics,† the quantity of iron ore produced in the Grand Duchy of Luxemburg in 1894 was 3,958,280 tons, 4577 workmen being employed.

There were 7 ironworks with a total of 23 blast-furnaces, and employing 1924 workmen daily.

There were 8 foundries, employing 383 workmen and producing 8328 tons of cast iron. The production of pig iron in 1894 was 679,816 tons.

IX.—ITALY.

Iron Trade Statistics. — The total quantity of iron ore raised in Italy in 1894 amounted to 187,728 tons, valued at £83,566, an increase in value of £12,259. This increase in value was due to the rise in price of Elba ores from 7s. 4d. the ton to 8s. 9d. The

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* *Stahl und Eisen*, vol. xvi. pp. 264–265.
† *Comité des Forges*, Bulletin No. 1032.

quantity of this ore that was raised showed a diminution, amounting to 3166 tons on the year. In Piedmont and in Lombardy the production showed no decrease.* In all Italy there were 39 iron mines at work, affording employment to 2178 men.

In addition to the quantity of ore above mentioned, there was raised from the mines of Monte Argentario 5810 tons of manganiferous iron ore. The quantity of Elba ore exported during the year was 176,393 tons.

Six blast-furnaces were in blast in 1894. These produced 10,329 tons of pig iron, as compared with 5 active furnaces making 8038 tons in 1893. The out-turn of the iron and steel works, on the other hand, showed a diminution, their production in 1894 having amounted to 196,343 tons.

The production of coal showed a diminution of 45,954 tons. The total quantity of coal raised in 1894 was 271,295 tons, valued at 5s. 7d. per ton. Of peat 34,911 tons were won, an increase of 7063 tons as compared with the previous year.

In the year 1894 the output of iron from the province of Carrara was 39,000 tons, and of steel, 32,702. The province of Rome produced 2600 tons of iron and 19,872 tons of steel. The output of iron in Milan province was 34,505 tons, and in Florence 31,520 tons. 9919 workmen were employed in the iron industry of Italy in the year 1894, and the value of the total production was' estimated as follows :—Iron, 32,218,000 lire (£1,289,000); and steel, 16,769,000 lire (£671,000).

The mineral production of Italy for '1894 may be summarised as follows : †—

	Metric Tons.
Iron ore	187,728
Manganiferous iron ore	5,810
Manganese ore	760
Coal and lignite	271,294
Asphalt and bitumen	60,493
Petroleum, crude	2,854
Graphite	1,570

In addition, 12,000 cubic metres of natural gas were produced. Half the value of the minerals at the mines is furnished by the sulphur mines, which occupy 30,339 of the total number of miners, who amount to 51,994 in number. Of these the coal mines employ 2347,

* *L'Industria*, vol. iv. p. 668.

† *Revista del Servizio Minerario*, through the *Engineering and Mining Journal*, vol. lxi. p. 276.

and the iron mines 2178 men.   In the production of gaseous hydro-carbons only one man was engaged.

The metallurgical products of Italy for 1894 were as follows : *—

	Metric Tons.
Pig iron	10,329
Iron castings	10,060
Wrought iron	141,729
Steel	54,614
Rolled plates	5,750
Briquettes, mineral	506,534
Briquettes, wood, peat, &c.	21,370
Asphalt and bitumen	7,820
Petroleum, refined	1,640

The number of men employed in the iron and steel industries was 11,084.

X.—JAPAN.

Iron Industry.—According to Klobukowski,† iron ore is found in a number of provinces, especially in Rikuchin, Kozuké, and Iwaki, in the form of magnetite, with from 62 to 65 per cent. of iron.   Iron sand is found on the coast of Izumo, Rikuzen, and elsewhere.   Red and brown hæmatite are also met with.   For smelting purposes fur-naces of fireclay are used, with tuyeres made of clay and powdered charcoal, hand bellows being used.   In Rikuchin, in furnaces 23 feet high, with hydraulic blast, each furnace smelts from $3\frac{3}{4}$ to $4\frac{1}{2}$ tons of ore a day, yielding 50 per cent. of iron and consuming 6 tons of char-coal.   A large ironworks has been built here, with 4 blast-furnaces, 12 puddling-furnaces, rolling-mills, coke-ovens, &c.   The magnetite is self-fluxing.   In 1895 Japan imported iron and steel to the value of about 8,000,000 *yen*, rails being about one-fourth of this.

According to Wada,‡ ex-chief of the Mining Bureau of Japan, sur-veys have extended over only a tenth of the iron-bearing strata of the country; but he estimates that the mines of Iwate would alone pro-duce 30,000,000 tons.   It is estimated that 17,200 tons will be re-quired annually to relay the rails already in use.   The present imports of railway rails and material amount to 430,000 tons.

    * *Revista del Servizio Minerario*, through the *Engineering and Mining Journal*, vol. lxi. p. 276.

    † *Echo des Mines*, vol. xxi. p. 1511.

    ‡ *Engineering News*, New York, vol. xxxv. p. 233.

XI.—*RUSSIA.*

Iron Trade Statistics.—In 1894 the output of coal in Russia amounted to 526,785,000 poods (1 pood = 36 lbs.), 14·5 per cent. in excess of the output in the previous year. This increase is mainly due to an increase in the output of the Donetz basin, which rose from 239,761,000 poods in 1893 to 293,869,000 poods in 1894. The output of the Dombrowa basin (Russian Poland) is steadily increasing, and rose to 202,397,000 poods in 1894. The outputs of the other coalfields of Russia have either made no progress in recent years, or but to a very slight extent.* In 1894 the production of pig iron was in round numbers eighty million poods, or nine and a half millions more than in the previous year. The out-turn of steel rose from 23,763,500 poods in 1893 to 30,090,000 in 1894, or 27 per cent. The production of malleable iron, on the other hand, diminished from 28,100,000 poods in 1893 to 27,574,500 in 1894, or about 2 per cent. The production of rails is increasing rapidly, and in 1894, 14,805,000 poods were made, as compared with 10,165,000 in 1891. The diminution in the production of malleable iron is not due to any diminution in the consumption, for the imports of foreign malleable iron have increased in the same period from 5,295,000 poods to 10,333,000 poods. Of the total quantity of pig iron produced in Russia in 1894, 42,752,000 poods were charcoal iron, and 34,536,000 coke pig iron. The largest portion of the increase in the out-turn of iron and steel occurred in South Russia. The output of iron ore rose in the Urals from 51,916,000 poods in 1893 to 61,863,000 poods in 1894, and in South Russia, from 38,788,000 poods to 56,745,000 poods, but in Russian Poland there was a diminution in the output, which fell from 11,436,000 poods in 1893 to 10,002,000 poods in 1894.

The output of manganese ore showed, on the whole, a slight diminution. In the Caucasus, owing to the opening of a new line of railway, there was an increase from 10,403,389 poods in 1893 to 11,193,066 poods in 1894, and in the Urals the output rose from 88,000 poods in 1893 to 159,443 in 1894. In South Russia, on the other hand, the output diminished considerably, having fallen from 4,739,933 poods in 1893 to 3,562,732 poods in 1894.

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* *Wiestn. fin. prom. i torg.*, 1895, p. 1990; *Chemiker Zeitung,* vol. xx. p. 104.

Iron Trade Imports.—In the first half-year of 1895,* the iron trade imports into Russia include the quantities named below, similar statistics for the first halves of 1894 and 1893 being also shown :—

Material.	First Half of		
	1895.	1894.	1893.
Pig iron { A	3,351	4,465	3,312
{ B	987	1,318	993
Steel rails { A	470	262	124
{ B . . .	202	107	75
Other kinds of iron and { A . .	6,419	5,367	3,243
steel named { B . .	3,643	3,101	2,205
Iron and steel machinery, { A . .	1,314	1,243	815
all kinds { B . .	1,889	1,784	1,398

A represents the quantities in thousands of poods, and B the values in thousands of gold roubles. The total values of all the imports into Russia in the first halves of the three years mentioned amounted in value to 48·5, 46·9, and 39·6 millions of gold roubles.

The Petroleum Industry.—The output of crude petroleum in Russia in 1895 amounted to 376,977,987 poods, or about 22 per cent. more than in 1894. In the Caucasus, oil is now being sought for at a number of new places, including the neighbourhood of the mouth of the Kura River, near the Alat railway station, and near Derbent and Petrowsk. The Grosni district is being exploited on an important scale. The oil obtained here, however, is not nearly so valuable for illuminating purposes as is the Baku oil, as it yields only 20 per cent. of illuminating oil.†

The Donetz Coalfield.—G. Reymond ‡ gives some extracts from a report dealing with the state of the mining and metallurgical industry in the Donetz district for the year September 1894 to September 1895. In that period, the coal produced amounted to ·3,349,130 tons. Of this, 1,000,000 tons were used in miscellaneous industries and for private consumption, 932,540 for railways, 764,580 for metallurgical

* *Stahl und Eisen,* vol. xv. p. 1070.
† *Chemiker Zeitung,* vol. xx. p. 174.
‡ *Bulletin de la Société de l'Industrie Minérale,* vol. ix. pp. 629–638.

works, 302,540 for navigation, 297,910 for sugar factories, and 47,290 tons for gasworks. The total was produced by 218 concerns, of which 15 produced 80 per cent.

The quantity of coal exported in 1894 from the collieries adjacent to the Kursk - Charkow - Asow and Katharin · railway amounted to 329,269 waggon-loads, weighing 197,561,700 poods. The output of coal from these collieries has increased rapidly in recent years.[*]

XII.—*SPAIN.*

Mineral Statistics.—The preliminary statistics collected and published by Don Ramon Oriol [†] show the coal production of Spain in 1895 to have been as follows:—

	Metric Tons.
Coal	1,774,560
Lignite	46,000

According to official statistics [‡] there were raised in Spain in 1894 5,352,353 tons of iron ore, 736 tons of argentiferous iron ores, and 1,659,274 tons of coal; 299 iron ore mines were in active operation, employing 12,926 workpeople. In addition there were 473 collieries giving employment to 15,174 men, and 67 brown-coal mines which employed 562 men. The quantity of brown coal raised was 48,460 metric tons.

Seventeen metallurgical works gave employment to 9,025 workpeople and produced 123,798 tons of pig iron; 54,214 tons of weld-iron, and 92,851 tons of steel.

Exports of Pig Iron.—In 1895 the export of pig iron from Spain amounted to 22,669 tons as compared with 48,538 tons in 1894. The total quantity of iron ore exported amounted to 5,248,192 tons.[§]

Bilbao Ironworks.—The Sociedad Altos Hornos, of Bilbao, made ‖ an imposing show at the Bordeaux Exhibition, with plans and photo-

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[*] *Stahl und Eisen,* vol. xv. p. 933.
[†] *Anuario de la Mineria de España* (Madrid, 1896), p. 104.
[‡] *Revista Minera,* vol. xlvii. p. 20.
[§] *Anuario de la Mineraria de España,* 1896, p. 106; *Revista Minera,* vol. xlvii. pp. 42, 50, 64.
‖ *Colliery Guardian,* vol. lxx. p. 747.

graphs of its blast-furnaces, iron and steel works, and samples of raw
and finished iron and steel, with rods tied into knots cold, and sub-
mitted to other torturing processes in order to show the quality of the
metal.   The company's ironworks, known as Nuestra Señora del
Carmen, are situated at El Desierto, Baracaldo, five miles from Bilbao,
and occupy an area of 139,338 square yards.   The three blast-furnaces
are capable of turning out 300 tons of iron daily, part of which is
rolled into finished iron, for consumption in the peninsula, as well as
being exported, while the remainder is used for making special cast-
ings.   There are two 10-ton converters, with place for a third ; and
on an average fifteen casts are made per twelve-hour day.   As a rule,
the molten pig from the blast-furnaces is charged directly into the
converters, but there are two large cupolas for melting the pigs if neces-
sary, as well as three smaller cupolas for melting the addition of
wrought iron and ferro-manganese.   The open-hearth furnace is capable
of producing 12 tons at each operation.   The company, which employs
about 3,000 men, turns out yearly on an average 45,000 tons of rails
and ship iron, 12,000 tons of puddled iron, 10,000 tons of bar steel,
6,000 tons of plates, and 6,000 tons of castings, with 3,000 tons of
sleepers, roofs, and boilers.

The Port of Bilbao.—During the year 1894–1895 the coal imports
of Bilbao amounted to 576,960 tons, and general cargo to 186,200,
whilst the exports of ore were 4,032,846 tons, and general cargo
only 186,173 tons.   These figures show the enormous importance of
this port to the mining and metallurgical industries, and works of con-
siderable magnitude are in progress to improve the accommodation
and safety.   In addition to the work of improving the river naviga-
tion, two moles are being built, with a length of 1585 and 1198 yards,
to enclose an area of about 740 acres.   The heavy seas of the last two
days of December 1894 made extensive breaches in the works.   To
remedy this the foundation was continued on the inner side, and
on it were laid huge boxes 42½ feet long by 23 feet square, built
up of sheet iron 0·24 inch thick, and divided by partitions into six
compartments.   Each box weighed 28 tons, and was filled with twelve
concrete blocks, so that they weighed about 1300 tons when in
position.   Two hundred of these were used on the foundation, and
the superstructure built on them.[*]

* *Revista Minera*, vol. xlvii. pp. 3-4.

XIII.—*SWEDEN*.

Mineral Statistics.—The official statistics * show that the average outturn of each active blast-furnace was 3192 tons in 257 days, or 12·43 tons per day. Almost without exception charcoal was the fuel employed. In only a few instances, as in the manufacture of spiegeleisen at the Schisshyttan, was coke (from the United Kingdom) employed.

From the collieries of the Schonen district 213,634 tons of coal were produced in 1894, 13,701 tons more than in 1893. The same collieries raised 129,617 tons of fireclay, 8852 tons less than in 1893. Of graphite, 105,630 tons were raised.

Altogether there were employed in the mines and metallurgical works of Sweden in 1895, 25,452 workpeople. The number of magnetic separators now in use in the treatment of old waste-heaps is 10, one more than in the preceding year.

In 1894, 145 blast-furnaces were in blast at 126 different works, 50 furnaces being held in reserve; 56·39 per cent. of the pig-iron made was forge pig-iron, and 40·19 per cent. Bessemer and open-hearth metal.

Malleable iron and steel were made at 152 works in 19 districts. The furnaces in use included the following, the respective totals for the preceding year being shown in brackets: Lancashire hearths, 337 (349); Franche-Comté hearths, 39 (39); Walloon hearths, 24 (24); scrap hearths, 14 (12); and puddling furnaces, 4 (4). Ingot metal was made in 31 (30) Bessemer converters, 32 (30) open-hearths, and 5 crucible steel furnaces. Cement steel was made in 5 (7) furnaces.

In 1894, 55·8 per cent. of the products of the iron and steel works was weld iron, and 44·7 per cent. ingot metal. In the previous year these totals were respectively 59·8 and 40·2 per cent. With regard to the shaping of bar iron and steel, 29·5 per cent. of the total was shaped under hammers, and 70·5 per cent. by rolls; rolls are gradually replacing hammers for this purpose.

* *Bidrag till sveriges officiela Statistik*, 1895, p. 11.

XIV.—*UNITED STATES.*

Iron Trade Statistics.—The following is a summary of the statistics for 1895 published by the American Iron and Steel Association : *—

	Tons.
Pig iron	9,446,308
Bar, hoop, and structural iron and steel . . .	3,005,765
Iron and steel wire rods	791,130
Plate and sheet iron and steel	991,459
Bessemer steel rails	1,299,628
Open-hearth steel rails	697
Iron rails	5,810
Bessemer steel	4,909,128
Open-hearth steel	1,137,182
Crucible steel	67,666
Blister and patented steel	858
All kinds of crude steel	6,114,834
Iron ore	15,957,614

In the thirteenth edition of the "Directory to the Iron and Steel Works of the United States," † full details are given of all the works in the United States on January 1, 1896. Among the works enumerated and described are the following :—

	No.
Blast-furnaces	469
Blast-furnaces building	10
Rolling mills and steelworks	463
Puddling furnaces	4408
Bessemer steelworks	43
Converters	99
Open-hearth steel plants	88
Crucible steelworks	45
Cut-nail mills	53
Wire works	23
Wire-nail works	53
Tin-plate works	69

Imports and Exports.—According to the report of the United States Bureau of Statistics,‡ the imports of iron and steel into

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* "Annual Statistical Report" (Philadelphia 1896), p. 61. A copy of this volume has been presented to the library of the Institute by Mr. J. M. Swank.

† Published by the American Iron and Steel Association. Philadelphia, 1896. A copy of this volume has been presented to the library of the Institute by Mr. J. M. Swank.

‡ "Statistics of the American Iron Trade." Philadelphia, 1896.

the United States in the calendar years 1894 and 1895 were as follows :—

Description.	1894.	1895.
	Tons.	Tons.
Iron ore	168,541	524,153
Pig iron	15,582	53,232
Scrap iron and steel	2,380	6,066
Bar iron	9,228	20,049
Iron and steel rails	300	1,447
Hoops or band iron	805	15
Ingots, blooms, slabs, billets, &c.	9,494	26,255
Sheet, plate, and taggers iron or steel	28,795	14,531
Tin plates	215,068	219,545
Wire rods of iron or steel	22,607	26,834
Wire and wire rope	4,288	5,773
Anvils	406	502
Chains	291	474
	309,249	378,208

During the same period the exports were as follows :—

Description.	1894.	1895.
	Tons.	Tons.
Pig iron	24,482	26,164
Band, hoop, and scroll iron	100	198
Bar iron	3,147	3,329
Wheels (No.)	14,662	14,106
Ingots, bars, and rods of steel	1,463	3,147
Nails and spikes—		
Cut	8,180	7,875
Wire, wrought, horseshoe, and others, with tacks	1,738	2,367
Wire	26,512	29,475
Plates and sheets—		
Iron	2,227	423
Steel	829	812
Railroad bars or rails—		
Iron	1,327	6,792
Steel	12,229	8,807

The imports of iron ore for 1895 are officially reported to be 524,153 tons, an increase of 355,612 tons over the previous year.* Most of the ore came from Spain and Cuba, but there were some imports from Algeria and Greece. The manganese ore imports were 80,717 tons, an increase of 36,052 tons, mostly from Russia.

* *Engineering and Mining Journal*, vol. lxi. p. 169.

XV.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For the purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended :—

Country.	Year.	Production in Tons.
United Kingdom	1895	189,661,362
Australia—		
New South Wales . . .	1894	3,672,076
New Zealand	1894	719,546
Queensland	1894	270,705
Tasmania	1894	30,922
Victoria	1894	171,659
Austria, coal	1894	9,572,952
,, lignite . . .	1894	17,332,538
Hungary, coal	1894	1,037,322
,, lignite . . .	1894	3,180,715
Belgium	1895	20,414,849
Canada	1895	3,512,504
Cape of Good Hope . . .	1894	69,690
France	1894	27,459,137
Germany, coal	1895	79,163,615
,, lignite . . .	1895	24,713,198
India	1894	2,820,652
Italy, lignite	1894	271,294
Japan	1893	3,317,188
Natal	1894	141,010
Russia	1894	7,498,000
Spain	1895	1,774,560
Sweden	1894	399,898
United States	1895	172,426,366

A similar summary showing the production of pig iron is as follows :—

Country.	Year.	Production in Tons.
United Kingdom	1895	7,895,675
Austria	1894	742,372
Hungary	1894	329,985
Belgium	1895	829,135
Canada	1894	50,166
France	1895	2,005,889
Germany	1895	5,788,798
Italy	1894	10,329
Japan	1893	17,501
Russia	1894	1,300,000
Spain	1895	179,752
Sweden	1894	462,809
United States	1895	9,446,308

In the above summaries, tons of 2240 lbs. are used in giving the production of the United Kingdom, the Colonies, and the United States, and metric tons of 2204 lbs. are used for other countries.

According to a statement from the Board of Trade, issued as a parliamentary paper, the countries which import coal in excess of the amount they export are Russia, Sweden, France, Spain, Italy, and Austria-Hungary; and of British possessions, Canada, Victoria, Queensland, Tasmania, New Zealand, the Cape, and British India, together with all the smaller colonies, with the sole exception of Labuan (Borneo). In the United Kingdom, Germany, Belgium, and the United States most, if not the whole, of the coal consumed is of native production. Of Russia's consumption, 79 per cent. is her own coal, 17 per cent. is British coal, and 4 per cent. comes from other countries. In Sweden 88 per cent of the coal consumed is British, in France 12 per cent., in Spain 50 per cent., in Austria-Hungary less than 1 per cent., and in Italy nearly the whole is of British origin.

The number of persons employed in coal production in various countries in 1894 was as follows:—United Kingdom, 665,747; Germany, 299,627; Belgium, 117,103; France, 131,587; Japan (1893), 30,345; the United States (1893), 363,309; British India, 43,197; Canada, 9654; New South Wales, 9131; New Zealand, 1899; and the Cape, 1601.

The Iron Trades of Germany and the United Kingdom.—

The following comparison is drawn between the British and German iron trades : *—

	Thousands of Metric Tons.			
	Germany.		United Kingdom.	
	1893.	1894.	1893.	1894.
Pig iron produced	4986	5380	6830	7365
Pig iron worked up . . .	5041	5350	5990	6534
Rolled iron made	1079	1041	1259	1302
Ingot iron and steel made . . .	3162	3617	2949	3110
Total finished products . .	4241	4658	4208	4412
Exports of finished products . .	1041	1207	1897	1739
Home consumption	3200	3451	2311	2673

* *Kölnische Zeitung; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xliii. p. 552.

Belgian and German Iron Industries.—The report of the delegation organised by the British Iron Trade Association to investigate
the economic conditions of the iron and steel industries in Belgium
and Germany has been published.* The delegation was composed
of fourteen representatives—J. Patchett, W. H. D. Gladstone, W.
Thackray, C. Parnaby, J. R. Winpenny, J. T. Wright, and J. S.
Jeans representing the employers; and E. Trow, J. Cox, W. Aucott,
S. Harris, P. Walls, T. Carlton, and J. Cronin representing the workmen. The report covers twenty-three pages, and deals with the
statistical position of the iron industry, fuel, iron ore supplies, cost of
pig iron, wages, mechanical appliances, productiveness of workmen,
rates and freights, workmen, management, workmen's houses and
funds, labour, royalties, capital expenditure, technical education, syndicates, effect of the basic process, effect of newer plants, and economy
in details. Shorthand notes of the visits to the various works are given
in appendices.

* *The Iron and Steel Industries of Belgium and Germany.* London, King & Son, 1896
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JORDAN, C. H. "*Tabulated Weights of Iron and Steel.*" Fifth edition. 8vo, pp. 579. London : E. & F. N. Spon. (Price 7s. 6d.)

KLASEN, L. "*Grundriss-Vorbilder von Gebäuden aller Art. Abth. 4. Fabriken für die Metall- Industrie.*" 4to, pp. 113, with 209 illustrations and 2 plates. Leipzig. (Price 8s.)

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